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PROPULSION AND POWER RAPID RESPONSE RESEARCH AND DEVELOPMENT (R&D) SUPPORT

Delivery Order 0011: Advanced Propulsion Fuels R&D

Subtask: Advanced Propulsion Fuels Research and Development Support to AFRL/RQTF

Gary R. Bessee, Scott A. Hutzler, Edwin Frame, Douglas M. Yost, George R. Wilson, Nigil Jeyashekar, and Adam C. Brandt

Southwest Research Institute (SwRI®)

DECEMBER 2012
Interim Report

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14. ABSTRACT

The overall aim of this program was to provide subject matter expertise and technical and engineering services to UTC/AFRL in support of the evaluation of emerging synthetic aviation fuels. Tasks included the following: (1) Elastomer-Fuel Compatibility Studies For Dynamic Seal Applications, (2) An Experimental Study on Laminar Flame Speeds and Extinction Stretch Rates of Jet Fuels, Alternative Fuels and Fuel Blends, (3) R8 Rotary Fuel Injection Pump Wear Testing, (4) Evaluation of JP-8 at High Temperature in the Ford 6.7L High Pressure Common Rail Diesel Engine, and (5) Fit-For-Purpose Testing of Alternative Aviation Fuels.

15. SUBJECT TERMS

alternative fuels, synthetic aviation fuel; Fischer-Tropsch Fuel (FT); fuel certification; hydrotreated renewable jet (HRJ); iso-paraffinic kerosene (IPK); synthetic paraffinic kerosene (SPK), ATJ (alcohol-to-jet)

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PREFACE

This report was prepared for the Universal Technology Corporation (UTC), 1270 North Fairfield Road, Dayton, Ohio, 45432-2600 under Contract Number FA8650-08-D-2806-0011 with the Air Force Research Laboratory's Propulsion Directorate (AFRL/RQPF). Ms. Michele Puterbaugh (Contractor, Universal Technology Corporation) was the task order program manager for this effort. Ms. Amanda Welch (Contractor, Universal Technology Corporation) was the task order assistant program manager for this effort. Mr. James Klein, (Subcontractor, Klein Consulting LLC), was the technical leader in support of Dr. James T. Edwards, Senior Scientist, of the Fuels Branch (AFRL/RQPF), Energy/Power/Thermal Division, Propulsion Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio. The research reported herein was performed by Southwest Research Institute, 6220 Culebra Road, San Antonio, TX and covers the period of 10 October 2010 – 10 November 2012. (Technical editing and technical comments by Mr. James Klein for UTC are included as noted.) This effort was funded by the Air Force Research Laboratory.

1.0 EXECUTIVE SUMMARY

The overall aim of this program was to provide subject matter expertise and technical and engineering services to UTC/AFRL in support of the evaluation of emerging synthetic aviation fuels. Tasks included fit-for-purpose testing, engine and pump testing, flame speed analysis, and material compatibility studies. A summary of each task is provided below.

1.1 Elastomer-Fuel Compatibility Studies for Dynamic Seal Applications

Southwest Research Institute® (SwRI®) designed and built a laboratory bench top apparatus that simulates turbojet engine environments containing reciprocating seals for the evaluation of elastomeric O-rings exposed to alternative fuels and fuel blends. Tests were conducted at 200°F and 80 psig. The test was terminated when fuel leaked past O-rings and the performance of the O-ring was quantified by failure time. The three elastomer materials selected for dynamic tests were Fluorosilicone, Viton, and Buna-N O-rings. Four elastomer pairs from each material were tested with the same fuel to obtain failure time. Pre-test and post-test property measurements (thickness, hardness, and volume swell) were measured and the percentage changes in properties were computed.

The results indicate that this test is capable of showing a comparative effect of alternative fuels of varying aromatic content on dynamic seal performance.[1]

1.2 An Experimental Study on Laminar Flame Speeds and Extinction Stretch Rates of Jet Fuels, Alternative Fuels and Fuel Blends

The most important governing parameter in the laminar flamelet regime of a turbulent diffusion flame, in a gas turbine combustor is laminar flame speed and it primarily accounts for diffusivity and reactivity of the fuel-air mixture. In a turbulent diffusion flame, the flame is non-uniformly stretched, resulting in variation of local equivalence ratios in the flame. For high values of flame stretch, the reactive-diffusive mixture in the flame breaks apart, causing flame extinction.

This report presents laminar flame speed and extinction stretch rate measurements of seven test fuels that include conventional jet fuel (JP-8), alternative fuels (R8, Camelina and Tallow HRJ), and its respective 50/50 fuel blends. Based on laminar flame speeds and extinction stretch rates, the report investigates if the resistance to flame extinction has been altered in the 50/50 alternative fuel blend relative to JP-8.

The overall conclusion is that the 50/50 R8–JP-8 fuel blend will have higher resistance to flame extinction at lean-blow-out conditions in a gas turbine combustor compared to the other two alternative fuel blends. 50/50 Camelina–JP-8 blend and 50/50 Tallow HRJ–JP-8 will have the same level of resistance to flame extinction as JP-8 fuel. The above conclusions were based on laminar flame speeds and extinction stretch rates measured at higher equivalence ratios in a constant volume combustion chamber.

1.3 R8 Rotary Fuel Injection Pump Wear Testing

Initial tests[2] with R8 HRJ fuels revealed severe wear and extreme life reduction of rotary fuel injection pumps for diesel engines. The untreated R8 HRJ fuel caused performance degrading

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[1] Technical editing by Mr. James Klein, Klein Consulting LLC
[2] Refer to AFRL-RZ-WP-TR-2011-2020, Appendix I

wear on rotary fuel injection pumps within 25-hours of operation on the untreated fuel. Previous work with low lubricity synthetic kerosene fuels showed those fuels responded well to the addition of a corrosion inhibitor/lubricity improver (CI/LI) additive to extend the life of the rotary fuel injection equipment.

The impact of minimal QPL-25017 CI/LI additive levels on fuel injection pump durability with R8 fuel was investigated. The minimal additive levels were determined by the additive concentration that resulted in an ASTM D 5001 Ball-On Cylinder Lubricity Evaluator (BOCLE) wear scar targets of 0.75-mm and 0.85mm. The resulting test fuels were R8 + 8.5-ppm DCI-4A with a 0.75-mm BOCLE wear scar, and R8 + 2.75-ppm DCI-4A with a 0.83-mm BOCLE wear scar.

Although the 0.75-mm BOCLE wear scar R8 fuel completed 500-hours of operation there was performance degradation of the fuel injection pumps, such that engine peak torque would be decreased, the engine peak power would be decreased, and with the cranking speed delivery at zero, an engine would be unable to start with these pumps. This additive treatment level R8 fuel would not be recommended for diesel engine use.

The 0.83-mm BOCLE wear scar R8 fuel completed only 183-hours of operation due to substantial over fuelling by the fuel injection pumps, such that exhaust black smoke would increase at all conditions, the cranking speed delivery increase would cause white smoke, possibly too rich to ignite, and half of the fuel injectors exhibited performance degradation that would impact engine operation and emissions. This additive treatment level R8 fuel is ineffectual in providing proper diesel engine rotary fuel injection pump wear protection.

1.4 Evaluation of JP-8 at High Temperature in the Ford 6.7L High Pressure Common Rail Diesel Engine

Commercial off-the-shelf (COTS) diesel engines are available to the U.S. Military that employ High Pressure Common Rail (HPCR) fuel injection systems. Use of aviation jet fuel in addition to diesel fuel in these diesel engines is being required to provide maximum flexibility in the battlefield as part of the Single Fuel Forward policy. Overall performance and endurance of these HPCR systems has the potential to vary with use of military or alternative fuels due to critical chemical and physical property differences compared to standard diesel fuels.

To understand critical fuel related impacts, performance and endurance testing was conducted using a fired engine equipped with a modern fuel lubricated HPCR fuel system using JP-8 at elevated inlet temperatures (70°C, maximum specified fuel system temperature, versus 32°C for conventional testing) treated with 9 ppm of a QPL-25017 additive that resulted in a 0.58 mm BOCLE wear scar diameter. Testing was completed using a Ford 6.7L V8 turbocharged diesel engine. The engine used was tested in its “export” configuration, which does not utilize Exhaust Gas Recirculation (EGR) or exhaust after-treatment systems. Testing was completed following a modified version of the U.S. Army 210-hr Tactical Wheeled Vehicle Cycle (TWVC).

The engine fueled with elevated temperature JP-8 was successfully operated over the entire test duration without experiencing any unusual fuel-related operational conditions or hardware failures. At the minimum lubricity enhancing treat rate, the tested JP-8 fuel provided adequate component protection and system performance despite being operated at the maximum specified diesel fuel inlet temperature of the system. Post-test fuel injection system inspection found tested components to be in similar condition compared to all previous fuels tested. Results from testing

support the durability of the fuel lubricated HPCR fuel system utilized on the Ford 6.7L with a military specified JP-8 fuel at elevated temperatures.

1.5 Fit-For-Purpose Testing of Alternative Aviation Fuels

The overall aim of this effort was to provide fit-for-purpose testing and subject matter expertise to UTC and AFRL to support the evaluation of emerging synthetic aviation fuels. This report contains information on the evaluation of various alternative aviation fuels including: R8, GEVO ATJ (alcohol-to-jet), Neste Oil NExBTL HRJ (from waste oils), and Rentech FT-SPK. This report also contains the results of some special topic studies including water solubility, speed-of-sound, and isentropic bulk modulus.

Although most of the fuels studied to date (particularly the 50/50 blends) would likely meet a standard jet fuel specification, each of the synthetic fuels in this study exhibit their own unique behavior imparted on the fuel by the particular feedstock. Some of the behavior noted in this report is critical to fuel performance such as additive response, water solubility, and distillation characteristics. This further reinforces the need for fit-for-purpose testing to identify those unusual characteristics and to ensure that they are not significantly outside our current experience with petroleum-derived jet fuels.

The cumulative work to date provides strong evidence that blends composed of 50% synthetic fuel (FT IPK, HRJ, ATJ, etc) and 50% petroleum-derived fuel will be more than adequate as drop-in replacements for current petroleum-based fuels.

2.0 REPORT CONTENTS

This report contains a compilation of results for selected tasks under contract FA8650-08-D-2806-0011 and should satisfy the following UTC subcontract agreements:

- 11S590001102C7

Three tasks under this effort have been reported separately and are not included in this document. They include the following:

- ***Evaluation of 50/50 Hydroprocessed Renewable Jet Fuel & JP-8 in the Ford 6.7L High Pressure Common Rail Diesel Engine***
  - SwRI Project No. 08-16246.03, D. M. Yost and A. C. Brandt,
  - Dated November 2012,
  - Sub Contract #11S590001102C7.
- ***Modeling of Properties of Conventional and Possible Alternate Rocket Propellants***
  - SwRI Project No. 08-16246.06, S. R. Westbrook, G. R. Wilson, and S. O'Brien,
  - Dated November 2012,
  - Sub Contract #11S590001102C7.
- ***AFRL-RZ-WP-TR-2011-2084, Analysis of Synthetic Aviation Fuels***
  - *Dated April 2011,*
  - Sub Contract #09S590001102C1.

The following tasks are documented in full standalone reports included as appendices:

Appendix A Elastomer-Fuel Compatibility Studies For Dynamic Seal Applications,

Appendix B An Experimental Study on Laminar Flame Speeds and Extinction Stretch Rates of Jet Fuels, Alternative Fuels and Fuel Blends,

Appendix C R8 Rotary Fuel Injection Pump Wear Testing,

Appendix D Evaluation of JP-8 at High Temperature in the Ford 6.7L High Pressure Common Rail Diesel Engine,

Appendix E Fit-For-Purpose Testing of Alternative Aviation Fuels.

NOTE: The terms R8 and R8 HRJ, and R-8 and R-8 HRJ are used interchangeably within this report.

APPENDIX A

ELASTOMER-FUEL COMPATIBILITY STUDIES FOR DYNAMIC SEAL APPLICATIONS

Prepared by

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A1.0 EXECUTIVE SUMMARY

Alternative jet fuels are typically comprised solely of paraffins and lack aromatic compounds. The absence of aromatic compounds does not provide the desired seal-swell characteristics and other needed *fit-for-purpose* (FFP) properties. There are potential concerns that the use of alternative fuels with little or no aromatic content will cause leaks due to insufficient seal swell. Static soak tests only provide an insight to seal swell characteristics for elastomer material compatibility with alternative fuels and do not simulate operating conditions in an actual engine environment. The current research need is to investigate the effect of alternative fuels on elastomer seals in a simulated turbojet engine environment. In light of this research need, the objective of this task is to investigate the impact of alternative fuels and fuel blends on performance and properties of elastomer seals in a dynamic seal test rig.

Southwest Research Institute® (SwRI®) designed and built a laboratory bench top apparatus that simulates turbojet engine environments containing reciprocating seals for the evaluation of elastomeric O-rings exposed to alternative fuels and fuel blends. Tests were conducted at 200°F and 80 psig. The test was terminated when fuel leaked past O-rings and the performance of the O-ring was quantified by failure time. The three elastomer materials selected for dynamic tests were Fluorosilicone, Viton, and Buna-N O-rings. Four elastomer pairs from each material were tested with the same fuel to obtain failure time. Pre-test and post-test property measurements (thickness, hardness, and volume swell) were measured and the percentage changes in properties were computed.

The results indicate that this test is capable of showing a comparative effect of alternative fuels of varying aromatic content on dynamic seal performance.[1] The reader should also note that an minimum acceptance criteria has not been defined for this test rig.[2]

With Jet-A fuel, it was concluded that the resistance to failure is least for Fluorosilicone O-rings followed by Buna-N O-rings. Viton O-rings had the highest resistance to failure. With the use of R8 fuel, the average performance of Fluorosilicone O-rings decreased by half and the performance of Buna-N and Viton O-rings with R8 fuel, was drastically reduced by a factor of 17 and 10 respectively. The possible reasons for the poor performance of elastomers with R8 fuel could be a combination of lack of aromatics, thermal effects and/or fuel lubricity. The percentage changes in elastomer properties (thickness, hardness, and volume swell) were computed. Based on these changes in properties, it can be concluded that the Fluorosilicone O-rings failed by softening and the volume changes for Fluorosilicone could not be interpreted to yield a specific conclusion. With R8 fuel, Buna-N O-rings failed by hardening and volume shrinkage. The data indicates that failure for Viton O-rings can either occur by softening or by hardening and that these O-rings failed due to net volume shrinkage.

Average elastomer performance increased significantly with 50/50 R8-JP-8 fuel blend compared to R8 fuel. However, the elastomer performance with the alternative fuel blend does not rise to the performance level of Jet-A fuel. The average performance of all three elastomer materials with the alternative fuel blend was reduced by 50% compared to conventional jet fuel. For the alternative fuel blend, Buna-N O-rings failed by hardening and shrinkage in volume. While,

[1]Technical editing by Mr. James Klein, Klein Consulting LLC

[2]Technical editing by Mr. James Klein, Klein Consulting LLC. A criteria centered around the Buna-N material of 100 hours failure time (average) has been suggested. This suggestion has not been accepted nor approved as of this writing.

Viton O-rings failed softening, the change in volume indicates both shrinkage and swell. Viton O-rings showed notable difference in elastomer properties for R8 fuel and the alternative fuel blend. The above conclusions were represented as performance-property envelopes for the three elastomer materials with R8 and 50/50 R8–JP-8 fuel blend.

The future research should focus on evaluating the effect of types of aromatic compounds and its percentage composition in the fuel, on elastomer performance. Research should emphasize on determining the minimum aromatic content in the fuel for satisfactory engineering performance of the elastomer material. The research should also include measurement of lubricity to check for correlations between performance and fuel lubricity. The ultimate goal of this task is to determine if a given elastomer is compatible with the test fuels under dynamic conditions in comparison to reference fuels (Jet-A or JP-8). To reach this goal, SwRI formulated a set of criteria to define fuel-material compatibility based on the performance-property envelopes of test fuels and reference fuels. The criteria are:

1. If the performance-property envelope of the test fuel falls within the range of envelope of the reference fuel, then the test fuel completely satisfies fuel-material compatibility under dynamic conditions.
2. If the performance-property envelope of the test fuel (especially fuel blends) falls completely outside the range of the reference fuel envelope, then the test fuel does not satisfy the material compatibility requirements. The deviation of the test fuel envelope from the reference fuel envelope will indicate the extent to which the test fuel fails to meet the material compatibility standards under dynamic conditions.
3. If the performance-property envelope of the test fuel overlaps with that of the reference fuel, then extent of material compatibility will be defined by the extent of overlap.

The above criteria will help us determine the minimum aromatic content required in the fuel to bring the performance level of the elastomer to the same level as conventional jet fuel.

A2.0 INTRODUCTION AND OBJECTIVE

SPK, HRJ, and upcoming alternative fuels are typically comprised solely of *iso*- and *n*-alkanes and do not contain heteroatoms, aromatics, or cyclic compounds. Aromatic compounds are believed to provide seal-swell and other needed *fit-for-purpose* (FFP) properties. There are potential concerns that the use of alternative fuels with little or no aromatic content will cause leaks due to insufficient seal swell. Thus, the composition or chemistry of alternative fuels has an impact on the properties and performance of elastomer seals in aviation engine hardware. In addition to fuel chemistry, the performance and properties of elastomer seals are also affected by axial stresses on moving or sliding surfaces and high temperatures in a turbojet engine environment. Several static soak tests[i,ii,iii,iv] have provided an insight to the seal swell characteristics and elastomer material compatibility with alternative fuels. However, static soak tests do not simulate operating conditions in an actual engine environment.

The current research need is to investigate the effect of alternative fuels on elastomer seals in a simulated turbojet engine environment. In light of this research need, the objective of this task is to investigate the impact of alternative fuels and fuel blends on performance and properties of elastomer seals in a dynamic seal test rig. The test rig wets the elastomer seals with alternative fuel and subjects it to axial stresses at high temperatures on a reciprocating shaft. The dynamic seal test rig simulates the operating environment of a turbojet fuel system. The failure time of the elastomer material, causing leaks is used to evaluate the performance of elastomer seals with different types of alternative fuels. The task evaluates elastomer seal compatibility with baseline fuels and compares them to alternative fuels in terms of failure time. Pre-test and post-test measurements such as elastomer thickness, hardness and volume change will also be used to examine the effect of alternative fuels on properties of elastomer seals.

A3.0 TECHNICAL BACKGROUND

A3.1 Elastomer Material-Fuel Interaction

The chemical interaction of fuel and elastomer material is a two-way process:

Absorption of fuel by elastomer material:

The elastomer material selectively absorbs components of the fuel. The selective rate of absorption depends on the structure and composition of polymer chains in the elastomer material[v]. Fuel absorption results in elastomer swelling, which is a typical characteristic for O-rings seals. In reciprocating shafts, the increase in volume and thickness of the O-rings seals the shaft and the bore surface, preventing fuel leaks. The ratio of difference between the final O-ring thickness and the bore size to the original O-ring thickness, expressed as a percentage, is called elastomer squeeze. Under dynamic conditions, the O-ring absorbs fuel to swell and maintain a level of elastomer squeeze that is necessary for shaft seals. The maximum recommended squeeze for dynamic seals should be limited to 16% due to friction and wear[vi].

Extraction of elastomer components by fuel:

The fuel extracts plasticizers, stabilizers, and other processing materials that are added to enhance elastomer flexibility and resilience. When such materials are extracted by the fuel, the elastomer hardens; small cracks start to appear in the stressed area of the O-ring cross-section, and the seal's overall volume decreases. Volume shrinkage is a typical characteristic observed when extraction of elastomer material by fuel is greater than absorption of fuel by the elastomer. Unlike selective absorption of fuel components, the rate of extraction of elastomer material depends to a greater extent on operating temperatures and fuel lubricity; and to a lesser extent on chemical interaction with the fuel. BOCLE results for R8 fuel yielded a wear scar of 0.92 mm. However, the 50/50 R8–JP-8 fuel blend had a wear scar of 0.54 mm. This indicates that by blending JP-8, the lubricity of the R8 fuel is improved significantly. During the dynamic seal tests, the elastomer will be squeezed to approximately by 15% to reduce fuel permeation. The reciprocating motion that causes the wear due to interaction of the elastomer with the high temperature surface can be minimized by having a fuel blend with higher lubricity compared to the synthetic jet fuel.

A3.2 Effect of High Temperature

The three types of O-ring elastomer materials used in this work are Fluorosilicone, nitrile (Buna-N) and fluorocarbon (Viton). Fluorosilicone O-rings can be exposed to operating conditions up to 350 °F, while Buna-N O-rings can be operated to 250 °F, and Viton O-rings can be exposed to temperature to a maximum of 400 °F[vii]. For this task, the elastomers will be exposed to fuel temperatures of approximately 200°F in order to accommodate dynamic tests for all O-rings. The Buna-N O-rings in turbojet fuel systems are exposed to maximum fuel temperatures between 200 °F to 250 °F. Elastomers soften upon initial exposure to high temperatures. The increased exposure to high temperatures causes irreversible changes in the physical and chemical properties of the elastomer. The physical changes involve thickness, hardness, volume, tensile strength, and elongation. The chemical changes are due to thermally induced additional cross-linking in polymer chains, plasticizer loss, and oxidation. High operating temperatures accelerate extraction of elastomer components by the fuel. The physical and chemical changes that are thermally induced cause the elastomer to harden and/or crack, resulting in material failure. It should be noted that the soak test to measure the property changes

of the elastomer material, can be performed at a maximum temperature of 60 ^{o}C. However, this is not the maximum temperature that the O-ring is subjected to, in fuel system components.

A3.3 Failure Mechanism Under Dynamic Operating Conditions

Elastomer performance depends on a combination of chemical interactions and high temperature operating conditions. The elastomer materials are composed of polymers, which are highly polar molecules. Conventional jet fuels typically consist of hydrocarbons that are both non-polar saturated compounds and polar aromatic compounds. The polar aromatic compounds in the fuel interact with the elastomer material in two steps. In the first step, the polymer-polymer intermolecular bonds are broken in the elastomer material to form cavities large enough to fit the aromatic molecules. In the second step, the aromatic compounds occupy these cavities and create cross-links between the polymer chains through intermolecular bonding. This mechanism of absorption of the aromatic compounds causes volume swell of the elastomer material.

High operating temperatures cause physical and chemical changes to the elastomer material that result in shrinkage, hardening, and failure. Even though the elastomer is subjected to high temperatures, it continues to absorb aromatic molecules from the fuel that imparts the required volume swell to the elastomer for sufficient sealing under dynamic conditions. Thus, the rate of shrinkage and hardening due to thermal effects is compensated by a constant supply of aromatic molecules from the fuel. In isolation, the thermal effects would cause the O-rings to shrink and harden, due to the loss of plasticizers and absorption of fuel can offset these effects. The elastomer functions without failing as long as there is equilibrium between absorption and thermal effect. When the elastomer material becomes saturated with fuel, absorption of aromatic molecules from the fuel and the volume swell will stop. Further exposure to high temperature wears the elastomer material, resulting in failure. The failure time will depend on the type of material, aromatic components in the fuel, operating temperature, and other properties such as fuel lubricity.

A3.4 Dynamic Versus Static Soak Tests

Both static soak and dynamic tests account for elastomer-fuel interaction. However, static soak tests fail to account for the following elements of fuel-material compatibility studies:

1. Effect of axial stresses created by reciprocating motion that imparts additional wear on the elastomer material.
2. Effect of volume swell and elastomer squeeze on O-ring performance.
3. Effect of temperature that accelerates extraction of elastomer material by fuel causing hardening and surface stress cracks, resulting in seal failure.
4. Static soak test fails to account for practical relevance in regards to seals operating in turbo-jet fuel systems.

A comparison of dynamic versus static soak tests is listed in Table A-1.

Table A-1. Comparison of Static Soak Versus Dynamic Seal Tests

#	Elements of Material Compatibility Research	Static Soak Tests	Dynamic Tests
1	Elastomer-fuel interaction	Yes	Yes
2	Effect of axial stresses by reciprocating motion	No	Yes
3	Elastomer squeeze	No	Yes
4	Effect of high temperature	No	Yes
5	Practical relevance to turbo-jet fuel systems (engineering performance under comparable in-service conditions)	No	Yes

A4.0 DYNAMIC SEAL TEST RIG: OPERATING METHOD, ASSUMPTIONS, AND PROCEDURES

Turbojet engine fuel control systems employ sealing surfaces that move or slide over an elastomer sealing material. These seals are generally referred to as dynamic seals, and the usual configuration is an O-ring. SwRI designed and built a laboratory bench top apparatus[viii], which is shown in Figure A-1. This apparatus, called the dynamic seal test rig, will be used for the evaluation of elastomeric O-rings exposed to alternative fuels and fuel blends on a reciprocating shaft, under dynamic conditions. The test rig is designed to simulate temperatures ranging from 15^{o}F to 300^{o}F. The dynamic tests will be used to study the effect of alternative fuels on properties and performance of elastomeric materials.

A4.1 Test Rig: Principle Component and Construction

The dynamic seal test rig will simulate sealing conditions normally employed for sealing a shaft that reciprocates in its axial direction. Figure A-2 shows a cross-section drawing of the principal component of the test rig. A stainless steel shaft machined to highly precise dimensions (±0.005 inch) with test O-rings will be reciprocated in a heated aluminum block containing a precision bore. A small cavity at the end of each aluminum block, formed within the end caps, will collect fuel that leak past the O-ring under test. The "primary seal" will be the seal under test and the function of the "secondary seal" is to prevent fuel from leaking through the fuel collection cavity. The end cap is also sealed against the body via an O-ring seal (AS-568116). Two elastomeric O-rings (size AS-568-012) will be installed in the shaft. A 600-W band heater will control the fuel temperature within the central cavity to the desired test temperature. The fuel temperature should not exceed 300^{o}F. Type T thermocouples are located in test block to measure the actual temperature of each O-ring. The cavity temperature is controlled by measurements from only one of the thermocouples, but either one can be selected. The measured temperature is always monitored and displayed from both the O-ring locations.

Figure A-1. SwRI Dynamic Seal Test Rig

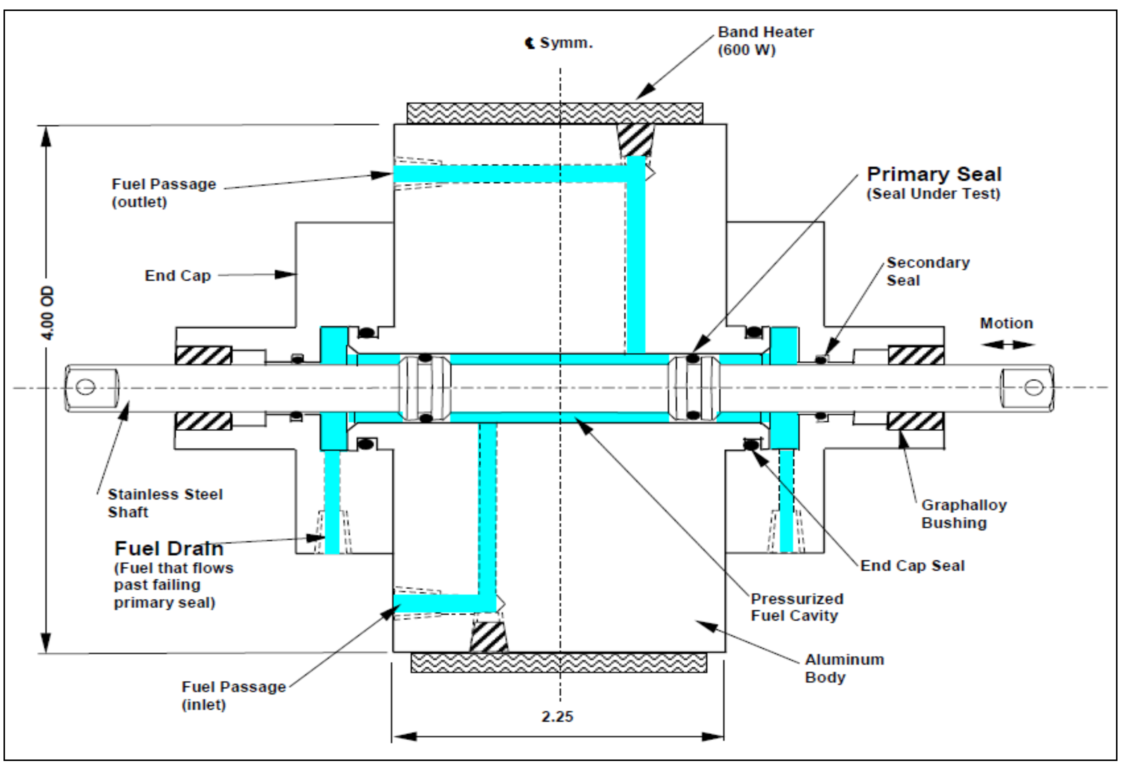

Figure A-2. Principle Component of the Test Rig (Test Block)

A4.2 Reciprocating Motion and Operating Load

The heated insulated block and shaft are supported on a rigid aluminum frame structure as shown in Figure A-3. The force needed to move the shaft is directed in the shaft's axial direction and precisely collinear on the axial centerline of the shaft. This is accomplished by a cross-head assembly incorporating two linear bearings. The force is supplied by a 12-rpm, ¾-horsepower gear-motor connected to a bell-crank mechanism. The shaft horizontal displacement is set to ±3/16". The stroke can be slightly adjusted by setting the radial distance of the bell-crank pin. The stroke should not be more than ±1/4" because the shaft must keep its stroke within the allowable length. The total distance traversed by the reciprocating shaft in one direction is 0.375". The angular velocity (ω), computed using rpm, is $(2\pi/5)$ *rad/s*.

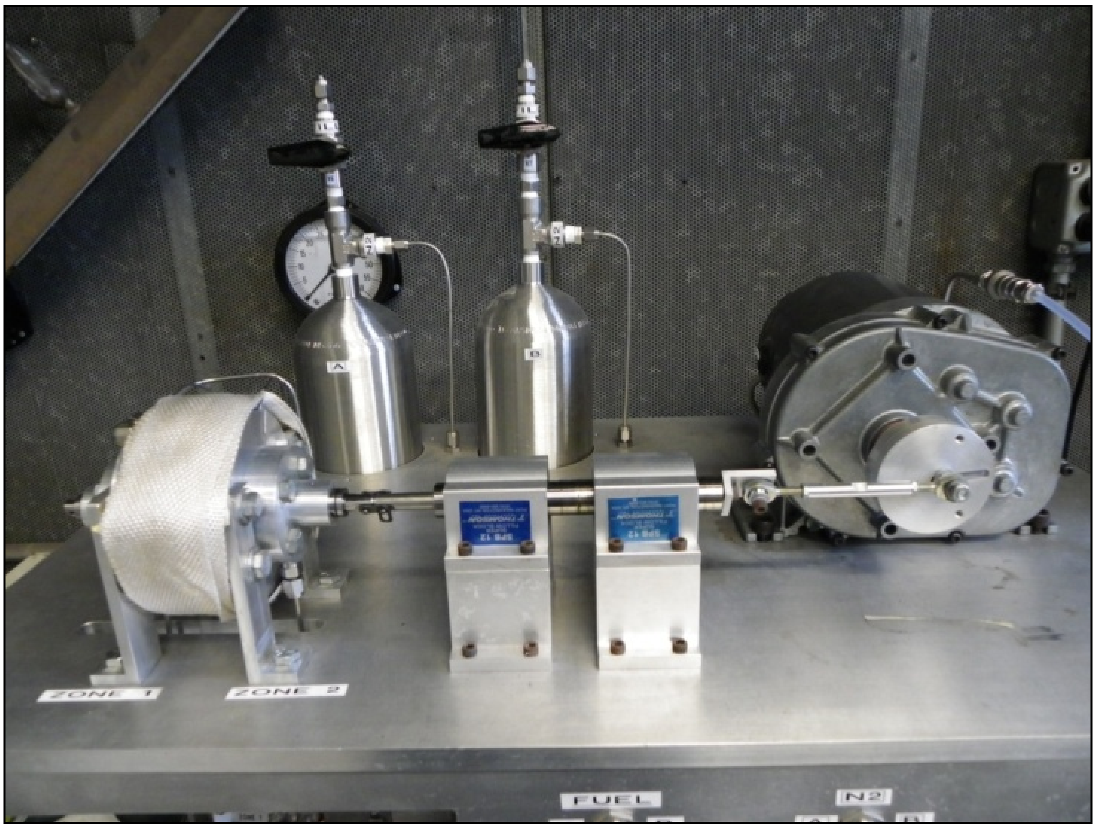

Figure A-3. Insulated Test Block Supported on a Rigid Aluminum Frame

The conversion of bell-crank rotary motion to reciprocating motion yields a sinusoidal velocity distribution. The corresponding force exerted on the O-rings is time dependent and is a function of the product of angular velocity and time (ωt). However, dynamics of motion is not the focus of this research. The time taken for a single stroke in one direction is 2.5 *s*, over a distance of 0.375". For a ¾-horsepower motor, the total load imparted to the O-rings due to reciprocating motion, per stroke in a single direction, is 146.79 KN.

A4.3 Test Rig: Operation, Failure Criterion and Switch Loading Capability

Two AS568-O12 O-rings of the same material will be mounted on a reciprocating shaft as shown in Figure A-2. The thickness, hardness, and volume of the O-rings are measured prior to installation. The fuel sample under investigation is filled in either of the two reservoirs. The

reservoir is pressurized to about 80 psig with Nitrogen. The 600-W heater is set to control the fuel temperature at 200°F. The motor sets the reciprocating shaft in motion prior to turning on the heater. The thermocouples are positioned closer to the internal wall of the test block (shown in Figure A-2). Fuel leaking past the seals under test is captured in two 5-ml graduated cylinders located just below the heated block. A photoelectric sensor is incorporated to stop the test after a certain volume of leaked fuel is collected in either of these graduated cylinders. The failure criterion is defined as the time needed for the seal to fail and leak fuel from the test block into the graduated cylinders. In dynamic seal tests the changes in elastomer properties and failure time provide an insight into seal performance with a variety of alternative fuels and fuel blends. The test rig is inspected every hour. The O-rings are declared to have failed if there is detectable leakage[3]. A maximum leak rate of 2.5 ml will trigger the photoelectric sensor to shut down the test rig. At failure, it is typical for all tests to leak fuel between 0.5-2.5 ml. A unique design capability of this test rig is its ability to switch fuels during a test run. The test can start with one particular fuel that is brought into contact with the O-ring seals and then switched to a second fuel with a different composition. This simulates a common situation that occurs in the field where there are frequent changes of fuel composition on elastomer. Two reservoirs and associated valves in the test rig are used to accomplish the switch loading manually. For the current tests, fuel switch loading evaluations have not been performed.

A5.0 TEST ARTICLES: ELASTOMERS AND TEST FUELS

The three elastomer materials selected for investigating the effect of fuel and dynamic motion are: Viton O-ring (AS568-O12), Fluorosilicone O-ring (F70 blue-O12), and Buna-N O-ring (AS568-O12). Four elastomer pairs from each material were tested with the same fuel to obtain failure time and change in properties. The actual internal diameter, for an AS568-O12 size O-ring, is 0.364±0.005" and the cross-section (thickness) is 0.070 ±0.003". The dynamic tests will be conducted with a matrix of representative fuel samples containing conventional jet fuel, alternative jet fuels, and fuel blends. The fuel samples are listed in Table A-2.

Table A-2. Representative Fuel Samples for Dynamic Seal Tests

#	Description	Qty.	POSF	SwRI CL#
1	Jet-A	10-gal	N/A	11-2459
2	R8	1 drum	5469†	10-0326
3	R8/JP-8 Blend	1-drum	7386‡	11-2128

† *POSF 5469 does not contain JP-8 additives, BOCLE = .92 mm*

‡ *POSF 7386 is 50% blend of JP-8 and additized R8. BOCLE=0.54 mm, Conductivity=102 pS/m*

[3]Technical editing by Mr. James Klein, Klein Consulting LLC

A6.0 ELASTOMER PROPERTY MEASUREMENTS: METHODS, ASSUMPTIONS AND PROCEDURES

A6.1 Thickness

Thickness of the O-ring is measured using a CDI micrometer instrument (model LG2110), as shown in Figure A-4. The micrometer can measure O-rings that are up to one inch thick. The pressure foot is lifted using a lever mechanism and is positioned on the center of the O-ring. The pressure foot is lowered gradually until it comes into contact with the O-ring, and the digital reading is recorded as the thickness of the O-ring. Measurements are repeated in triplicates, and the average thickness measurement is recorded.

Figure A-4. CDI Micrometer to Measure O-ring Thickness

Elastomer squeeze (ε) depends on the amount of compressive force applied to the seal (measured in pounds per linear inch), hardness of the seal (resistance to compression, measured by durometer reading), and the cross-section of the seal. Standard AS568-O12 O-rings will be installed on the shaft. The inner diameter of the O-ring is 0.364 ±0.005" and the thickness (cross-section) is 0.070 ±0.003". The total O-ring diameter including thickness is 0.504". The bore diameter in Figure A-2 is 0.484". Based on these values, the O-ring is compressed approximately 0.010" on either end of the sealing surface in the test block. The percentage compression in thickness, defined as elastomer squeeze, is estimated to be at least 15 %. The squeeze increases the surface area of the elastomer in the gland (shaft cavity where it is mounted) and reduces permeability of the fluid, providing adequate seal under dynamic conditions. The combined effect of fuel chemistry, reciprocating motion and temperature contributes to decrease in elastomer squeeze, resulting in seal failure and fuel leak. Therefore, a decrease in percentage thickness is a direct indication of decrease in elastomer squeeze. Irrespective of the elastomer material and the type of fluid medium, the elastomer material must be squeezed at least by 0.007" and the maximum squeeze for dynamic seal test should not exceed 16%. The dynamic seal test rig is designed to create a squeeze of approximately 15% that follows this guideline and at the same time minimizes permeation (diffusion) of fuel through the elastomer material.

A6.2 Hardness

The hardness of the elastomer material is rated using Shore M hardness on a scale from 0 to 100. The hardness scale is indicative of the elastic modulus (Young's Modulus) of the O-ring and is a measure of the stiffness of the material. Hardness measurements are recorded using Shore M Durometer (model 714). The Shore M durometer (Figure A-5) is used to collect accurate, repeatable hardness readings on soft elastomers that are too thin or too irregular in shape for measurement with a standard durometer, such as small O-rings. It is used for cross-sections 1.25 mm – 7 mm. The Shore test uses a hardened indenter, an accurately calibrated spring, a depth indicator, and a flat presser foot. The indenter protrudes from the middle of the presser foot and extends 2.5 mm from the surface of the foot. In the fully extended position, the indicator displays zero. When the indenter is depressed flat and is even with the presser foot's surface, the indicator displays 100. Therefore, every Shore point is equal to 0.0025 mm penetration (M scale is 0.00125 mm). To perform a test, the unit is placed on the sample so that the presser foot is held firmly against the test surface. The spring pushes the indenter into the sample and the indicator displays the depth of penetration. A deeper indentation indicates that the material is soft, and consequently the result would be a low indicator reading. The Shore A and D test method are the most commonly used scales. The M scale uses a very low force spring and was developed to allow testing very small parts, such as O-rings that cannot be tested in the normal A scale. Because different materials respond to the test scales in different ways, there is no correlation between the different scales. Shore test methods are defined in the following standards: ASTM D 2240, DIN 53 505, ISO 7619 Part 1, JIS K 6253, ASKER, and C-SRIS-010 1 (now obsolete).

Figure A-5. Shore M Durometer to Measure O-ring Hardness

A6.3 Volume

A density kit is used to determine the volume of an O-ring, and the measurements are usually made using an auxiliary liquid with a known density. In this case, water is used as the auxiliary liquid. The weight of the O-ring is measured in air and water before and after the dynamic test. The temperature of water (auxiliary liquid) is recorded to determine the density of water. The weight of the elastomer material in air (w_{air}) and water (w_{water}), along with the density of air (ρ_{air}) and water (ρ_{water}), is used to determine the volume of the elastomer material. The expression for computing volume (V) is shown in Equation 1. α is the weight correction factor 0.99985 to take the atmospheric buoyancy of the adjustment weight into account. Since the density of air does not vary significantly with temperature, ρ_{air} is set at a constant value of 0.0012 g/cm^3.

$$V = \alpha \cdot \left[\frac{w_{air} - w_{water}}{\rho_{water} - \rho_{air}}\right] \tag{1}$$

A density kit model ML-DNY-43 is used in combination with a balance model ML 104/03, as shown in Figure A-6.

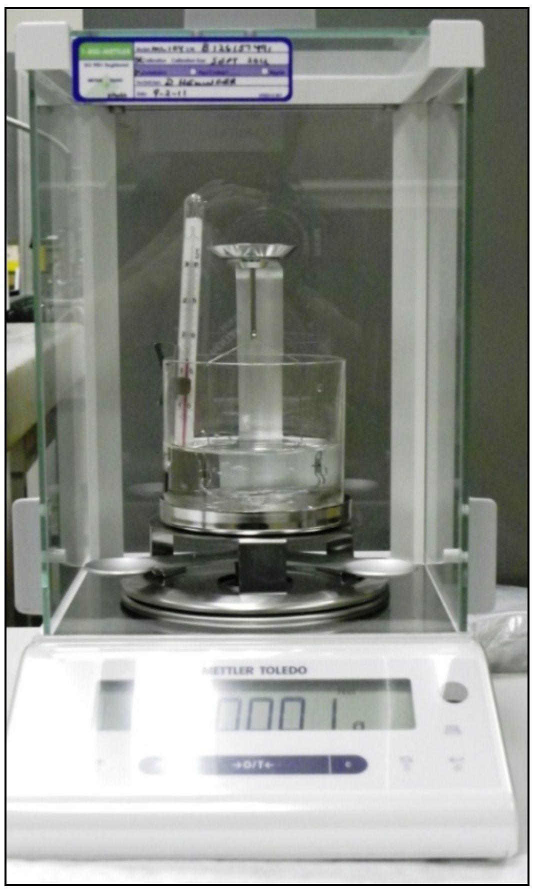

Figure A-6. Density Kit to Measure O-ring Volume

A7.0 TEST RESULTS: EFFECT OF FUEL ON ELASTOMER PERFORMANCE AND PROPERTIES

The dynamic tests for all three elastomer materials with Jet-A, R8, and R8–JP-8 50/50 fuel blend have been completed. Elastomer property measurements were not conducted on O-rings tested with Jet-A fuel, since the instruments listed in Sections A6.1–A6.3 were not available at that time. The test results for Jet-A fuel will be limited to describing the effect of fuel on the performance of elastomer material, in terms of failure time. Thickness, hardness and volume swell measurements were conducted for all the other O-rings tested with R8 fuel and R8–JP-8 50/50 fuel blend. For these fuels, test results include effect of fuel on elastomer properties and performance.

A7.1 Effect of Jet-A on Elastomer Performance

Fluorosilicone, Buna, and Viton O-rings that were tested in the dynamic seal test rig with Jet-A yielded the following results for failure time. Samples of Buna-N and Viton O-rings lasted more than 309 and 407 hours respectively. The exact failure time (maximum limit) for these materials were not determined. The performance of elastomer materials with Jet-A fuel is listed below and shown in Figure A-7.

1. Fluorosilicone: 42.1 – 136.4 hours
2. Buna-N: 183.4 – greater than 309 hours
3. Viton: greater than 407 hours

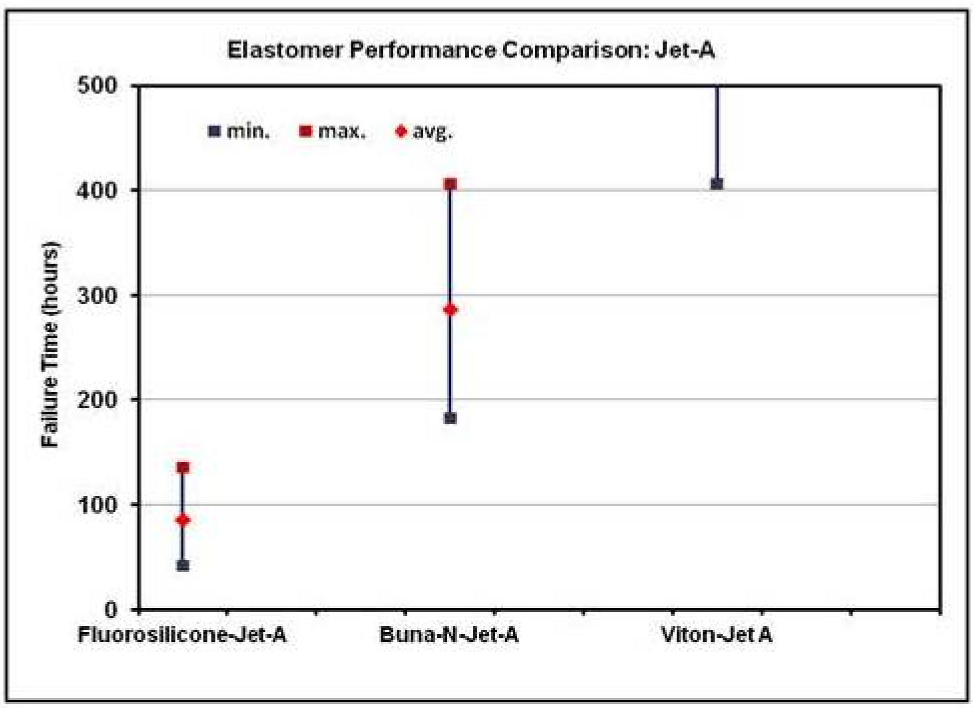

Figure A-7. Elastomer Performance with Jet-A

The range of failure time for Fluorosilicone O-rings (42.1 – 136.4 hours) is significantly lower compared to Buna-N O-rings (183.4 – >309 hours). Viton O-rings lasted for 407 hours and did not fail. The failure time for Viton O-rings is reported to be greater than 407 hours. Viton O-ring performance was superior under dynamic conditions compared to Buna-N and Fluorosilicone O-rings. Since the upper limit of failure time for Buna-N O-rings could not be determined based on the tests, the maximum failure time was set to be 407 hours. In terms of failure time, for Jet-A fuel, it can be concluded that the overall performance of Fluorosilicone O-rings are lower compared to Buna-N O-rings, which in turn are lower compared to Viton O-rings. Based on failure time, it can be inferred that the dynamic seal test rig can clearly differentiate the performance of elastomer materials in terms of failure time with the base fuel (Jet-A).

A7.2 Effect of R8 Fuel on Elastomer Performance

Four pairs of O-rings from each elastomer material were tested with R8 fuel, under dynamic conditions, at 200°F and 80 psig. The test ran until the elastomer failed, causing fuel to leak and collect in graduated cylinders below the test block. The thickness, hardness, and volume of the O-rings were measured before and after testing. A summary of the elastomer performance is listed in Table A-3. A comparison of the elastomer performance for Jet-A and R8 fuels, along with the averages for each material, is shown in Figure A-8. Table A-4 compares elastomer performance with R8 and Jet-A.

Table A-3. Elastomer Performance with R8 Fuel

Material	Temp. (°F)	Performance Range (hrs)	Average time (hrs)
Fluorosilicone	200	11.7 – 89.8	45.68
Buna-N	200	15.0 – 18.7	16.75
Viton	200	21.8 – 74.8	41.00

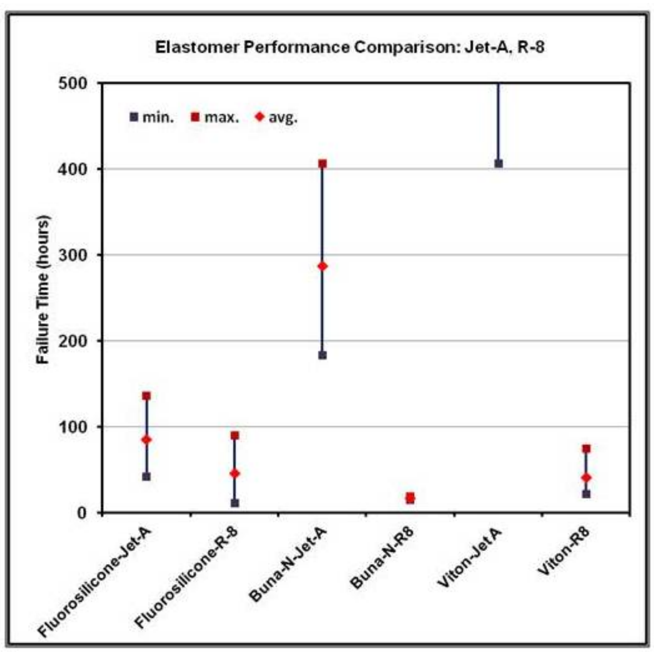

Figure A-8. Elastomer Performance Comparison: Jet-A v. R8

Table A-4. Jet-A versus R8 Elastomer Performance Comparison

#	Material	Elastomer Performance – Failure Time (hrs)			
		Jet-A		R8	
		Range	Average	Range	Average
1	Fluorosilicone	42.1 to 136.4	85.34	11.7 to 89.8	45.68
2	Buna-N	183.4 to >309	287.20	15.0 to 18.7	16.75
3	Viton	> 407	407.00	21.8 to 74.8	41.00

It can be inferred that Fluorosilicone and Viton O-rings have a larger spread in failure time, while Buna-N O-rings failed consistently between 15.00 – 18.70 hours. The average performance of Viton and Fluorosilicone O-rings are comparable. The average performance of Buna-N, Viton, and Fluorosilicone O-rings reduced with R8 fuel. The composition of R8 (in mass percent) is: paraffins – 90.20%; monocycloparaffins – 8.9%; and alkylbenzenes – 0.9%. These alkanes and cycloalkanes are relatively non-polar molecules, whereas the elastomers Buna-N (polybutadiene–acrylonitrile) and Viton (polyfluorocarbon) are comprised of polar polymer molecules. As a result, the chemical interaction of fuel with the elastomer is very limited, and with the lack of aromatic compounds, there is no volume swell.

All three elastomer materials were constantly exposed to 200°F operating temperatures and lower lubricity R8 fuel, which caused the O-rings to fail. In conclusion, for R8 fuel, the primary reason for elastomer failure under dynamic conditions is due to absence of aromatic compounds in the fuel, thermal effects, and lower fuel lubricity compared to Jet-A fuel. It should be noted that the average performance of Fluorosilicone O-rings decreased by half; from 85.34 hours with Jet-A to 45.68 hours with R8 fuel, whereas the performance of Buna-N and Viton O-rings with R8 fuel, was drastically reduced by a factor of 17 and 10 respectively. Thus, the lack of aromatics, thermal effects and fuel lubricity reduces the performance of Buna-N and Viton O-rings to the level of Fluorosilicone O-rings.

While all three materials were exposed to the same fuel at the same conditions, Fluorosilicone polymer material (fluorovinylmethyl silicone) has high friction tendencies, poor abrasion resistance and limited strength. This elastomer material is not suited for dynamic sealing applications[6] and is one of the contributing factors to poor performance with both Jet-A and R8 fuels. Thus, R8 does not greatly diminish the performance of the Fluorosilicone O-ring with respect to Jet-A fuel. It is recommended that Fluorosilicone should not be continued for future dynamic seal tests with conventional and alternative jet fuels.

A7.3 Effect of R8 Fuel on Elastomer Properties

Thickness, hardness and volume swell measurements were obtained as described in Sections A6.1-A6.3. The percentage differences in properties were averaged for each pair of O-ring. Table A-5 lists the percentage change in thickness, hardness, and volume swell for each elastomer.

Table A-5. Percentage Change in Thickness, Hardness and Volume

Material	Fail time (hrs)	Δ Thickness (%)	Δ Hardness (%)	Δ Volume (%)
Fluorosilicone	11.7 to 89.8	-8.44 to -17.60	-27.34 to -44.67	-14.25 to 7.29
Buna	15.0 to 18.7	1.69 to 3.84	2.17 to 11.25	-3.89 to 0.96
Viton	21.8 to 74.8	-12.40 to 3.69	-24.31 to 8.07	-9.68 to -0.28

There was an overall reduction in thickness and hardness of Fluorosilicone O-rings. The decrease in thickness and hardness measured as much as 17% and 44% respectively. Based on these changes in properties, it can be concluded that the Fluorosilicone O-rings failed by softening, with decrease in elastomer thickness and squeeze. The volume change cannot be interpreted to yield a specific conclusion.

Buna-N O-rings showed an overall increase in hardness. The maximum increase in thickness and hardness was measured to be 3.84% and 11.25% respectively. This result signifies that the elastomer hardness (Young's modulus) increased for Buna-N O-rings with R8 fuel. The increase in volume for the O-rings was not significant. Based on these changes in properties, it can be concluded that Buna-N O-rings failed by hardening and volume shrinkage. For Viton O-rings, the data indicates that failure can occur by softening or hardening and that the O-rings failed due to net volume shrinkage.

A7.4 Effect of R8–JP-8 Fuel Blend on Elastomer Performance and Properties

A summary of the elastomer performance is listed in Table A-6. A comparison of the elastomer performance for each material with Jet-A, R8, and 50/50 R8–JP-8 fuel blend is shown in Figure A-9. Table A-7 summarizes the elastomer performance and properties with Jet-A, R8, and 50/50 R8–JP-8 fuel blend.

Table A-6. Elastomer Performance with R8 – JP-8 Blend

Material	Temp. (°F)	Performance Range (hrs)	Average time (hrs)
Fluorosilicone	200	46.3 to 79.0	58.500
Buna-N	200	63.2 to 201.7	144.97
Viton	200	99.4 to 349.7	224.60

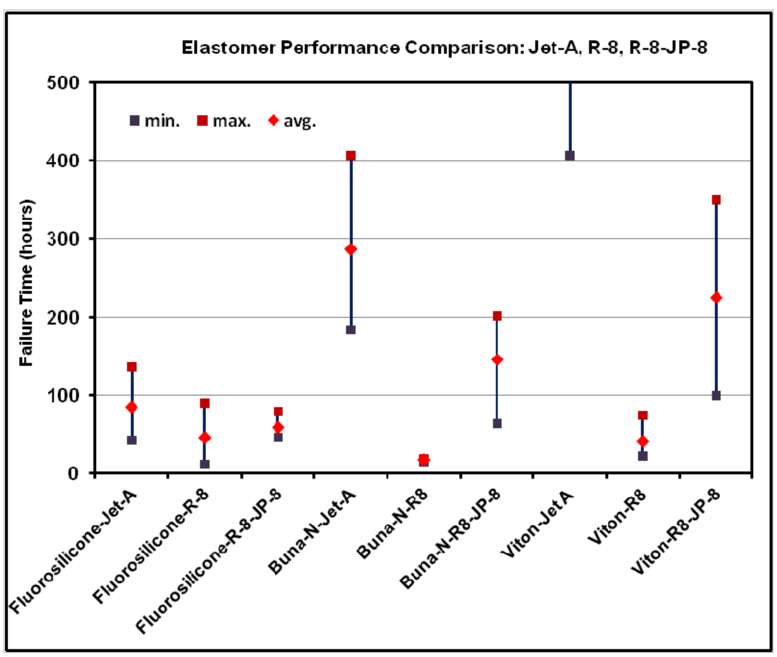

Figure A-9. Elastomer Performance Comparison: Jet-A, R8, and R8 – JP-8 Blend

Table A-7. Summary of Elastomer Performance

#	Material	Elastomer Performance – Failure Time (hrs)					
		Jet-A		R8		R8 – JP-8 Blend	
		Range	Average	Range	Average	Range	Average
1	Fluorosilicone	42.1 to 136.4	85.34	11.7 to 89.8	45.68	46.3 to 79.0	58.50
2	Buna-N	183.4 to >309	287.20	15.0 to 18.7	16.75	63.2 to 201.7	144.97
3	Viton	> 407	407.00	21.8 to 74.8	41.00	99.4 to 349.7	224.55

Average elastomer performance increased significantly with 50/50 R8-JP-8 fuel blend compared to R8 fuel. However, the elastomer performance with the alternative fuel blend does not rise to the performance level of Jet-A fuel. The average performance of all three elastomer materials with the alternative fuel blend was reduced by 50% compared to conventional jet fuel. The reader should note that a minimum acceptance criteria has not been defined for this test rig.[4]

In order to understand the reason behind this effect, future research must focus on evaluating the effect of types of aromatic compounds and its percentage composition in the fuel, on elastomer performance. Table A-8 provides the percentage change in hardness and volume of the elastomer material with R8, and 50/50 R8–JP-8 fuel blend. The difference in hardness and volume of the elastomer is computed based on pre-test and post-test property measurement and then expressed as a percentage change relative to pre-test property of the elastomer material. A positive sign for percentage change in hardness indicates hardening at failure and a negative sign indicates softening at failure. Similarly, a positive sign for change in volume indicates volume swell at failure, where as a negative sign indicated shrinkage.

Table A-8. Percentage Change in Thickness, Hardness and Volume

Material	Δ Hardness (%)		Δ Volume (%)	
	R8	50/50 R8–JP-8	R8	50/50 R8–JP-8
Fluorosilicone	-44.67 to -27.34	-40.28 to -33.57	-14.25 to 7.29	-9.34 to 11.10
Buna	2.17 to 11.25	1.78 to 8.83	-3.89 to 0.96	-2.88 to -1.59
Viton	-24.31 to 8.07	-23.31 to -14.72	-9.68 to -0.28	-7.81 to 2.39

For the alternative fuel blend, Buna-N O-rings failed by hardening and Viton O-rings failed by softening. In the case of percentage volume change, Buna-N O-rings failed by shrinkage. For the alternative fuel blend, current data indicates that some Viton O-rings failed by shrinkage, while others by volume swell. For R8 fuel, some Viton O-rings failed by hardening, while some by softening. This is evident based on the percentage hardness ranging from -24.31% to 8.07%. In terms of volume change, Viton O-rings shrunk with R8 fuel at failure. Therefore, Viton O-rings have shown notable difference in elastomer properties when comparing R8 fuel and the alternative fuel blend. More Viton O-rings must be tested to check the significance of volume swell with the alternative fuel blend.

For future research, the number of O-ring samples in each elastomer material must be increased to reach statistical relevance and to achieve conclusive results. Other than the aforementioned differences, the overall trends in hardness and volume change remains the same for both fuels for all three elastomer materials. The above data can be represented as plots of failure time versus

[4]Technical editing by Mr. James Klein, Klein Consulting LLC

changes in thickness, hardness, and volume swell as shown in Figure A-10. Such plots, called performance-physical property envelopes, enables direct comparison of overall elastomer fuel with conventional jet fuels, alternative fuels and fuel blends.

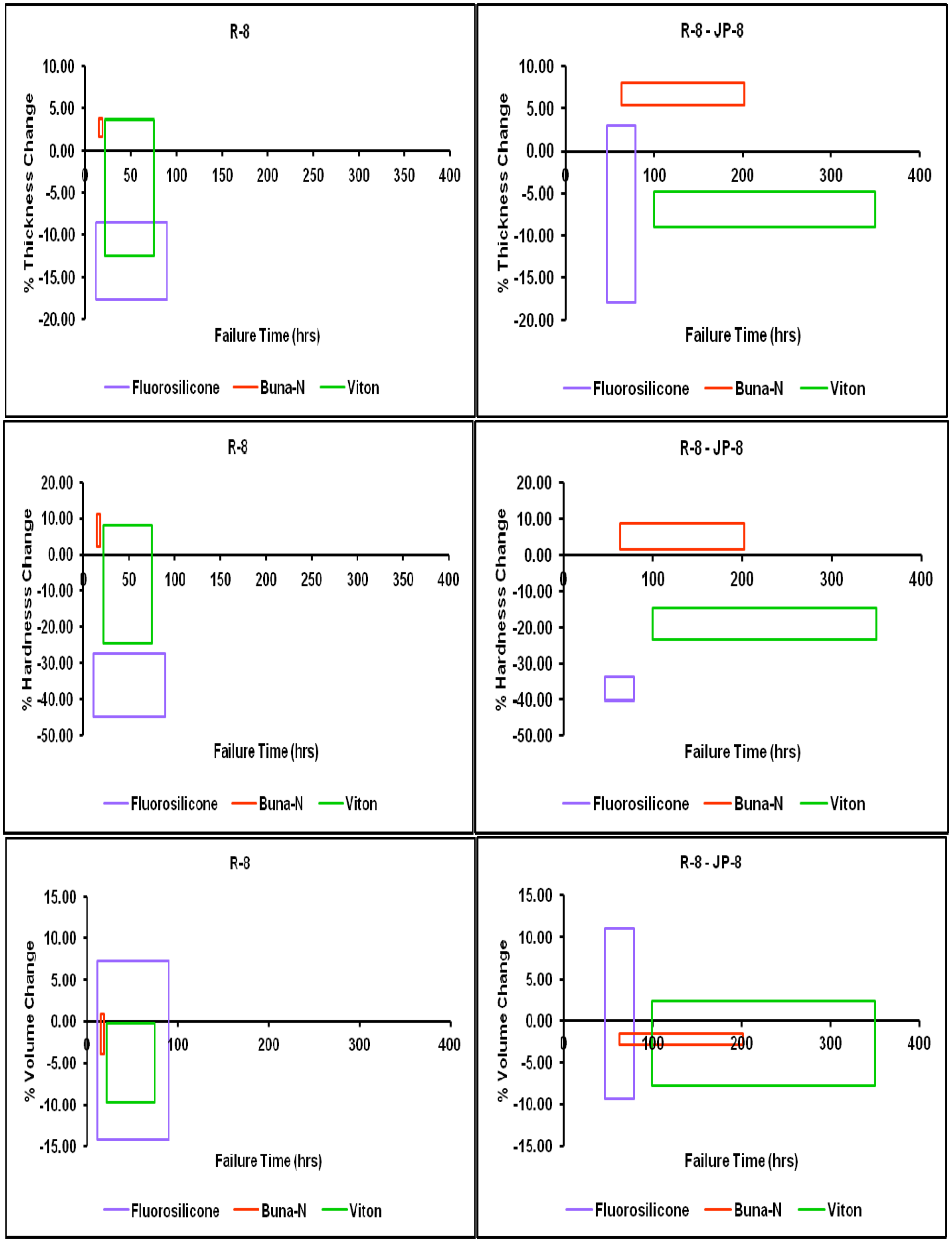

Figure A-10. Performance-Physical Property Envelopes of Elastomers with R8 v. R8–JP-8

A8.0 SUMMARY OF CONCLUSIONS

The results indicate that this test is capable of showing a comparative effect of alternative fuels of varying aromatic content on dynamic seal performance.[5] With Jet-A fuel, it was concluded that the resistance to failure is least for Fluorosilicone O-rings followed by Buna-N O-rings. Viton O-rings had the highest resistance to failure. With the use of fuel, the average performance of Fluorosilicone O-rings decreased by half and the performance of Buna-N and Viton O-rings with R8 fuel, was drastically reduced by a factor of 17 and 10 respectively. The possible reasons for the poor performance of elastomers with R8 fuel could be a combination of lack of aromatics, thermal effects and/or fuel lubricity. The percentage changes in elastomer properties (thickness, hardness, and volume swell) were computed. Based on these changes in properties, it can be concluded that the Fluorosilicone O-rings failed by softening and the volume changes for Fluorosilicone could not be interpreted to yield a specific conclusion. With R8 fuel, Buna-N O-rings failed by hardening and volume shrinkage. The data indicates that failure for Viton O-rings can either occur by softening or by hardening and that these O-rings failed due to net volume shrinkage.

Average elastomer performance increased significantly with 50/50 R8-JP-8 fuel blend compared to R8 fuel. However, the elastomer performance with the alternative fuel blend does not rise to the performance level of Jet-A fuel. The average performance of all three elastomer materials with the alternative fuel blend was reduced by 50% compared to conventional jet fuel. The reader should also note that a minimum acceptance criteria has not been defined for this test rig.[6] The significance of these results is discussed below.

For the alternative fuel blend, Buna-N O-rings failed by hardening and shrinkage in volume. While, Viton O-rings failed softening, the change in volume indicates both shrinkage and swell. Viton O-rings showed notable difference in elastomer properties for R8 fuel and the alternative fuel blend. The above conclusions were represented as performance-property envelopes for the three elastomer materials with R8 and 50/50 R8–JP-8 fuel blend.

A8.1 Implications of Dynamic Seal Test Results[7]

The initial tests with Jet A ranked the elastomer performance in the expected order:

1) Fluorosilicone – Worst
2) Nitrile – Mid range
3) Fluorocarbon – Best

This was anticipated based on known performance. The system was then evaluated with R8 HRJ (ASTM HEFA SPK) a type of material known to cause elastomer problems in fuel systems. Substantial losses in performance were seen with both nitrile and fluorocarbon. The next test was with a 50:50, volume %, blend of HRJ with JP-8, a system that has been approved for use by the Air Force and has shown satisfactory service. This testing once again ranked the elastomers in the appropriate order.

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[5]Technical editing by Mr. James Klein, Klein Consulting LLC
[6]Technical editing by Mr. James Klein, Klein Consulting LLC
[7]SwRI Notes on Dynamic Seal Test Device Report

The testing with refined Jet A took a long time due to the high performance of the fluorocarbon elastomers. If, however, the evaluation is made based off of the performance numbers generated for the 50:50 blend, then the testing becomes more approachable, time wise. The difference in median performance times between the neat HRJ and the blend can inform us about where reasonable performance limits can be established.

This type of testing will likely never be reduced to an ASTM standard method as it is just too time consuming to be anything other than a research tool. However, there are ASTM principles that can be brought forward in evaluating the results. In testing complex systems that rely on chemical processes, there is often significant scatter in the data. One resolution of that issue is to standardize on a minimum number of determinations (single runs on the apparatus at a given condition) required to generate a result (the effective performance at a given condition). In this testing, for instance, SwRI uses four (4) determinations to generate a result.

In future testing it should not be necessary to continue to use fluorosilicones. It served its purpose in proving that the test system could correctly show that it is not an appropriate material for use in mechanically actuated system. A further streamlining could be made by focusing on the nitrile elastomers, since they are known to be a service problem with straight paraffinic fuels. More work could be conducted on the rig by such a narrow focus. Once the nitrile performance was mapped against a number of fuel systems then it would be possible to do some selected evaluations using fluorocarbons.

A9.0 RECOMMENDED FUTURE RESEARCH

The future research should focus on evaluating the effect of types of aromatic compounds and its percentage composition in the fuel, on elastomer performance. Research should emphasize on determining the minimum aromatic content in the fuel for satisfactory engineering performance of the elastomer material. The research should also include measurement of lubricity to check for correlations between performance and fuel lubricity. Future tests could also investigate the effect of fuel switch loading. The ultimate goal of this task is to determine if a given elastomer is compatible with the test fuels under dynamic conditions in comparison to reference fuels (Jet-A or JP-8). To reach this goal, SwRI formulated a set of criteria to define fuel-material compatibility based on the performance-property envelopes of test fuels and reference fuels. The criteria are:

1. If the performance-property envelope of the test fuel falls within the range of envelope of the reference fuel, then the test fuel completely satisfies fuel-material compatibility under dynamic conditions.
2. If the performance-property envelope of the test fuel (especially fuel blends) falls completely outside the range of the reference fuel envelope, then the test fuel does not satisfy the material compatibility requirements. The deviation of the test fuel envelope from the reference fuel envelope will indicate the extent to which the test fuel fails to meet the material compatibility standards under dynamic conditions.
3. If the performance-property envelope of the test fuel overlaps with that of the reference fuel, then extent of material compatibility will be defined by the extent of overlap.

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A11.0 ACRONYMS & ABBREVIATIONS

Acronyms	Description
ρ	Density
°	Degree
”	Inches
%	Percent
ε	Elastomer squeeze
SwRI	Southwest Research Institute
ω	Angular velocity
rad/s	Radians per second
AS	Aerospace Standard
BOCLE	Ball-On Cylinder Lubricity Evaluator
C	Celsius
cm	centimeters
F	Fahrenheit
FFP	Fit-For-Purpose
g	gram
KN	Kilo-Newton
mm	millimeter
psig	Pounds per square inch gauge
rpm	Revolutions per minute
s	second
w	weight
W	Watts

APPENDIX B

AN EXPERIMENTAL STUDY ON LAMINAR FLAME SPEEDS AND EXTINCTION STRETCH RATES OF JET FUELS, ALTERNATIVE FUELS AND FUEL BLENDS

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B1.0 EXECUTIVE SUMMARY

The most important governing parameter in the laminar flamelet regime of a turbulent diffusion flame, in a gas turbine combustor is laminar flame speed and it primarily accounts for diffusivity and reactivity of the fuel-air mixture. In a turbulent diffusion flame, the flame is non-uniformly stretched, resulting in variation of local equivalence ratios in the flame. For high values of flame stretch, the reactive-diffusive mixture in the flame breaks apart, causing flame extinction. At this condition, the local flow speed exceeds the turbulent flame speed. The turbulent flame speed is the sum of laminar flame speed and the root-mean-square (r.m.s) fluctuation of average flow speed. The laminar flame speed component is a function of the fuel while the r.m.s component is a function of air flow parameter. Flame extinction occurs when the local flow speed in the turbulent diffusion flame is greater that the turbulent flame speed. Under constant operating conditions, when the r.m.s component of the flow velocity will remain a constant, laminar flame speed becomes a deciding factor with respect to flame extinction. This is especially true at lean-blowout operating conditions in a gas turbine combustor. This report presents laminar flame speed and extinction stretch rate measurements of seven test fuels that include conventional jet fuel (JP-8), alternative fuels (R8, Camelina and Tallow HRJ), and its respective 50/50 fuel blends. Based on laminar flame speeds and extinction stretch rates, the report investigates if the resistance to flame extinction has been altered in the 50/50 alternative fuel blend relative to JP-8.

Laminar flame speed measurements were made in a constant volume chamber for all the seven test fuels with equivalence ratios ranging from 0.6 to 1.1, with pressures ranging from 4.50 to 16.5 bar and temperatures ranging from 450 to 550 Kelvin. The total flame stretch rates were calculated based on the rate of expansion of the spherical flame inside the combustion chamber. The flame speed and total stretch rates were used to compute extinction stretch rate of fuels at each equivalence ratio. A six parameter mathematical model was developed based on the experimental data to calculate laminar flame speed based on pressures, temperatures and equivalence ratios. The correlation between measured and computed laminar flame speeds were greater than 95% for all the seven test fuels.

The laminar flame speed plots of R8, Camelina, Tallow HRJ and 50/50 blends are examined relative to JP-8. Over the entire range of equivalence ratios, pressures and temperatures indicated, the overall conclusion is that the laminar flame speed is higher for all three alternative fuels and fuel blends compared to JP-8. Investigating laminar flame speed versus equivalence ratio, for a pressure of 4.5 bar (65.3psi) and a temperature of 450 Kelvin (~350 ^{o}F), 50/50 blend of R8–JP-8 fuel has the highest laminar flame speed followed by R8 fuel, followed by JP-8. Blending R8 fuel with JP-8 increased the laminar flame speed of JP-8 beyond the level of R8. It can be concluded that R8–JP-8 blend will perform better at extinction conditions compared to JP-8. However, blending Camelina fuel to JP-8 did not increase the laminar flame speed to the level of alternative fuel. At low equivalence ratios, Camelina–JP-8 blend has a greater laminar flame speed value compared to JP-8. Therefore, it can be concluded that Camelina–JP-8 fuel blend will perform better compared to JP-8, at flame extinction conditions. Blending Tallow HRJ to JP-8 showed no significant increase in laminar flame speed values beyond Tallow-HRJ. Again, the 50/50 Tallow–JP-8 has a higher flame speed value compared to JP-8 and is expected to perform better when compared to JP-8 at flame extinction conditions. Based on the conclusions from all three alternative fuel blends, 50/50 R8–JP-8 fuel blend will have the highest flame speed and performs superior at flame extinction scenarios compared to JP-8, followed by 50/50 Camelina–JP-8 fuel blend and 50/50 Tallow–JP-8.

Based on extinction stretch rate data, it is concluded that by blending R8 to JP-8 resistance to extinction increases beyond the extinction stretch rate of R8 and that the 50/50 R8–JP-8 fuel blend will be highly resistant to extinction at near lean-blowout conditions. Blending Camelina to JP-8 increases the resistance to extinction marginally and that for all practical purposes, at lean-blowout scenarios, the resistance to extinction can be considered to be of the same magnitude as JP-8. Tallow HRJ has significantly higher resistance to extinction compared to JP-8. However, the extinction stretch rates for 50/50 Tallow HRJ–JP-8 and Tallow HRJ fuel are nearly identical. It can also be concluded that addition of JP-8 only fulfills the aromatic content requirement in Tallow-HRJ and does not contribute to any additional increase in resistance to flame extinction. At lower equivalence ratios, closer to lean-blow out conditions, it can be concluded that 50/50 Tallow HRJ–JP-8 blend will have nearly the same level of extinction stretch as JP-8.

The overall conclusion is that the 50/50 R8–JP-8 fuel blend will have higher resistance to flame extinction at lean-blow-out conditions in a gas turbine combustor compared to the other two alternative fuel blends. 50/50 Camelina–JP-8 blend and 50/50 Tallow HRJ–JP-8 will have the same level of resistance to flame extinction as JP-8 fuel. The above conclusions were based on laminar flame speeds and extinction stretch rates measured at higher equivalence ratios in a constant volume combustion chamber. Future research is recommended in the area of turbulent diffusion flames, laser and optical diagnostics to measure the actual local flame speed at local equivalence ratios in the flame. Further research is recommended to understand the variations in resistance to flame extinction by investigating the role of boiling point distribution and fuel chemistry.

B2.0 INTRODUCTION

Jet fuel is a mixture of several hydrocarbon components. A simulation of the combustion characteristics of jet fuel is not possible due to the lack of availability of reaction mechanisms for each fuel component. With upcoming alternative fuels and the changing specifications to accommodate the use of 50/50 jet fuel–alternative fuel blends, the computational simulation of combustion characteristics of such fuels will be practically impossible. While surrogate fuels have provided an insight into the combustion characteristics of simple hydrocarbons, it is not possible to prepare a surrogate for every alternative fuel or jet fuel–alternative fuel blend. Therefore, the fundamental combustion characteristics of jet fuels, alternative fuels, and fuel blends can be accurately predicted only based on experimental techniques by using the actual fuel.

The fundamental parameter that characterizes both laminar and turbulent premixed combustions within the laminar flamelet regime is the laminar flame speed. It is a global parameter that accounts for diffusivity and reactivity of mixtures. The common experimental techniques used to determine laminar flame speeds involve counter flow flames, flat flames and spherical expanding flames. Such experimental methodologies have the flame front locally affected by stretch effects. The total flame stretch is a combination of the flame curvature and the strain rate. Stretch effects induce modifications on the flame front structure and affects flame propagation. As a result, local equivalence ratios in the flame are altered by stretch rates, which lead to flame quenching.

This report provides a detailed experimental study to measure laminar flame speeds and total stretch rates of jet fuels, alternative fuels and jet fuel-alternative fuel blends. The overall goal of this research study is to determine the extent to which resistance to flame extinction of conventional jet fuel has been altered by blending it with alternative fuels. The results from this research work have direct implications on lean-blowout (LBO) operating conditions in a gas turbine combustor where turbulence is an additional factor that adds to flame stretch and enhances flame quenching. Based on laminar flame speeds and total stretch rates, a prediction can be made on which alternative fuel might perform poorly at LBO conditions in a gas turbine combustor.

B3.0 OBJECTIVE

The objectives of this research are:

a. To measure flame speed over a range of pressures, temperatures and equivalence ratios.

b. To calculate total stretch rates based on rate of expansion of the local flame front.

c. To calculate extinction stretch rates, Markstein lengths and present these quantities as a function of equivalence ratios.

d. To determine if the resistance to extinction has been altered by blending alternative fuels with conventional jet fuel.

These objectives are accomplished by conducting flame speed measurements in a constant volume measurement chamber for various operating pressures, temperatures and equivalence ratios. The total stretch rate is calculated based on expansion of the flame front with respect to the radius of the flame front. The extinction stretch rates are obtained at zero laminar flame speed conditions. A comparison of the plots of extinction stretch rates as a function of equivalence ratios will determine if the resistance to flame extinction has been altered by blending alternative fuels with conventional jet fuel.

B4.0 EXPERIMENTAL METHOD AND CALCULATIONS

The laminar flame speed measurements are obtained using a constant volume spherical chamber shown in Figure B-1. The spark plug in the bomb is positioned to ignite at the center of the bomb. The spherical chamber is insulated and the temperature of the chamber is controlled electronically to maintain the desired initial mixture temperature inside the chamber. K-type thermocouples are used to monitor the surface temperature and the mixture temperature within the chamber. Air-operated high pressure valves are placed at intake and exhaust to control the venting, purging, and evacuation of the chamber and the pressurization with fresh air. These valves are normally-closed and open when 12 atmosphere air is applied to these valves. A water-cooled piezo-electric pressure transducer is used to measure the pressure history during combustion. The equivalence ratio of the burned mixture is confirmed after each experiment by evacuating the combusted products past an automotive wide-range oxygen sensor (UEGO). A direct fuel injector is used to supply fuel and an accumulator is used to pressurize fuel. By controlling the pulse width of the signal applied to injector, injected fuel is controlled. Before using this fuel injection system, injector calibration is required for each fuel.

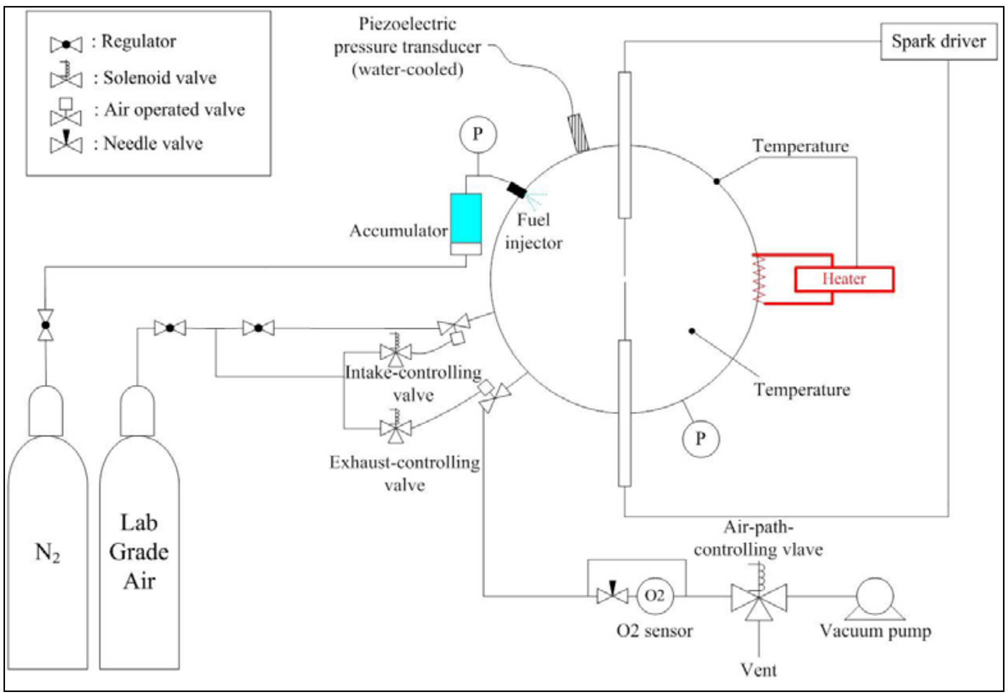

Figure B-1. Schematic of the Constant Volume Combustion Chamber

The experimental setup of the constant volume combustion chamber is shown in Figure B-2. The experimental procedure consists of five basic steps: Purge away residual or burned gas, evacuate the combustion chamber, supply fuel and air, ignite and measure phi, and repeat the experiments for several equivalent ratios.

Figure B-2. Experimental Setup of the Constant Volume Combustion Bomb

As ignition occurs at constant equivalence ratio, the pressure trace is recorded. The bulk temperature is calculated based on adiabatic process and using initial gas temperature. The flame speed is computed based on one dimensional CFD code and the algorithm is shown in Figure B-3.

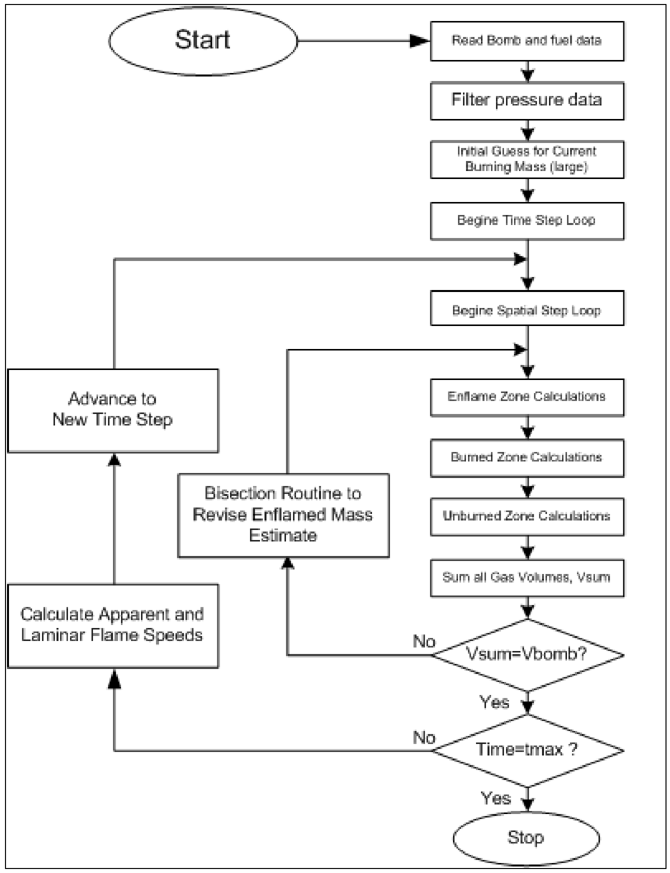

Figure B-3. One Dimensional CFD Code for Computing Flame Speed

There are two kinds of flame speeds that are identified during each time-step. The first-one is the "apparent" flame speed, which is simply the change in flame radius divided by the time-step size. The apparent flame speed includes effects due to laminar burning rate as well as the relative thermodynamic expansion or contraction of the unburned and burned gas regions. In other words, the laminar flame "rides" on the moving enflamed region. This flame speed can be inferred from traditional visual measurement methods. In the current calculation method, the apparent flame speed is computed numerically following the motion of the enflamed region of the chamber. The second kind of flame speed is called laminar burning velocity (without expansion effects), is calculated with attained current burning mass after the completion of the current time-step loop. Figure B-4 shows the laminar flame speed calculation model.

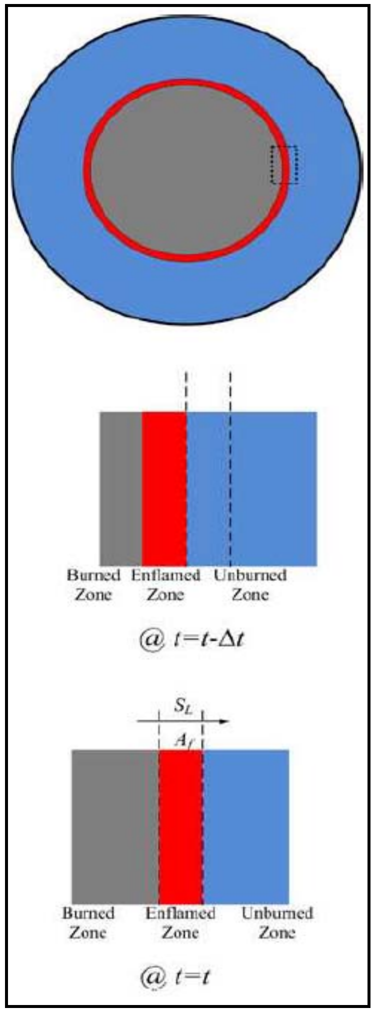

Figure B-4. Laminar Flame Speed Calculation Model

In this model, the volume of enflamed zone at the current time-step is considered. As the current time-step, the volume of the enflamed zone can be expressed with laminar flame speed, S_L, time-step size, Δt and flame area, A_f as follows.

$$V_{f@t=t} = S_L \cdot \Delta t \cdot A_f \rightarrow \tag{1}$$

A_f is the surface area of the current spherical flame which is calculated as $A_f = 4 \cdot \pi \cdot r^2{}_{@t=t}$. If the same volume is considered at one time-step before the current time-step, it can be also expressed with current burning mass, $M_{enflamed}$, gas constant, R, temperature, T and pressure, P as follows.

$$V_{f@t=t-1} = M_{enflamed} \cdot \left[\left(\frac{RT}{P}\right)_{t-1}\right] \rightarrow \tag{2}$$

With equations 1 and 2, for the same volume of the current time-step of the enflamed zone, the laminar burning velocity, S_L, is calculated with following equation.

$$S_L = \frac{M_{enflamed} \cdot \left[\left(\frac{RT}{P}\right)_{t-1}\right]}{A_f \cdot \Delta t} \rightarrow \tag{3}$$

During the experiment, the pressure (*P*), combustion vessel temperature (*T*), flame temperature (T_f) and flame radius (*r*) are recorded as a function of time (*t*) for each equivalence ratio (φ). The equivalence ratio is computed based on the combusted gases that are run through an emissions analyzer. A comparison between the set equivalence ratio and the computed equivalence ratio ensures the accuracy of the experiment. A six parameter correlation function, shown in equation 4, was developed based the recorded data.

$$S_L = [K_1 + K_2 \cdot (\varphi - \varphi_{max})^2] \cdot \left(\frac{T}{T_{ref}}\right)^{[K_3 + K_4 \cdot (\varphi - 1)]} \cdot \left(\frac{P}{P_{ref}}\right)^{[K_5 + K_6 \cdot (\varphi - 1)]} \rightarrow \tag{4}$$

The constants K_1, K_2, K_3, K_4, K_5, K_6, P_{ref}, T_{ref}, and φ_{max} were determined such that the root mean square between the modeled flame speed, in equation 4, and computed flame speed, in equation 3, is insignificant. The model equation describes flame speed characteristics of fuels over different equivalence ratios, temperatures and pressures.
The total stretch rate (α) of the expanding flame front is computed based on the flame radius (*r*) as shown in equation 5.

$$\alpha = \frac{2}{r} \cdot \frac{dr}{dt} \rightarrow \tag{5}$$

The total flame stretch rate is related to laminar flame speed through Markstein length (M) as given by equation 6, where S_0 is a constant.

$$S_L = S_0 - M \cdot \alpha \rightarrow \tag{6}$$

Markstein length indicates the sensitivity of laminar flame speed to flame stretch effects. For a flame extinction scenario, S_L becomes zero and corresponding extinction stretch rate is given by equation 7.

$$\alpha_{extinction} = \frac{S_o}{M} \rightarrow \tag{7}$$

A plot of $\alpha_{extinction}$ as a function of equivalence ratio will be used to assess if the resistance to extinction has been altered by blending alternative fuels with conventional jet fuel.

B5.0 TEST FUELS AND EXPERIMENT MATRIX

All fuel samples used in this research work was supplied to SwRI by the Air Force. The conventional jet fuel, JP-8, along with three alternative fuels, namely, R8, Camelina and Tallow fuels were chosen for this research study. The reason for choosing the three alternative fuels was either due to their differences in feedstock or manufacturing methods. Three fuel blend samples containing 50% JP-8 with 50% of each of the aforementioned alternative fuels were also provided by the Air Force. The carbon and hydrogen content in these fuel samples were determined using ASTM D5291. The nitrogen and sulfur contents were determined using ASTM D4629 and ASTM D 5453 respectively. The gross and net heat of combustion (H_C) of these fuels were determined using ASTM D4809. The composition and heat of combustion values of these fuels are summarized in Table B-1.

Table B-1. Composition and Heat of Combustion of Test Fuels

POSF-	SwRI CL12-	Fuel	C (%)	H (%)	S (%)	O (%)	AFR (φ=1)	H_C (Btu/lb)	
								Gross	Net
4751	3400	JP-8	85.99	13.93	0.036	0.043	14.82	19919	18622
5469	3401	R8	84.66	15.44	0.000	0.000	15.19	20095	18724
7386	3402	R8–JP-8 Blend	85.08	14.6	0.019	0.301	14.94	19986	18673
6152	3403	Camelina	84.45	15.38	0.000	0.170	15.14	20095	18707
6184	3404	Camelina–JP-8 Blend	85.26	14.58	0.018	0.142	14.96	20074	18745
6308	3405	Tallow	84.6	15.38	0.000	0.020	15.16	20184	18785
6406	3406	Tallow–JP-8 Blend	85.22	14.64	0.017	0.124	14.97	20111	18782

The experimental test matrix for the test fuels consists of equivalence ratios, operating pressures, temperatures and number of runs at each point. The range of equivalence ratios used for this study varies from 0.6-1.1. The range of pressure varies from 4.00-15.0 bar and the temperature varies from 450-550 K. Table B-2 provides the experiment matrix for one fuel. A set of flame speed data is acquired at a constant pressure and temperature range for four different equivalence ratios. This set consists of an average of 2 – 4 runs, with run duration from 5 to 25 milliseconds. Four sets of flame speed data is acquired for four pressure ranges. The temperature range for all the tests and all the runs are 450 – 550 K. This experiment matrix is used for all the seven test fuels and is listed in Table B-2.

Table B-2. Representative Experiment Matrix for One Fuel

Set	Φ	Pressure (bar)	Temperature (K)	Runs Number	Run Duration (ms)
Set – 1	φ_1	4.50-7.50	450-550	2 – 4	5 – 25
	φ_2				
	φ_3				
	φ_4				
Set – 2	φ_1	6.00-10.5	450-550	2 – 4	5 – 25
	φ_2				
	φ_3				
	φ_4				
Set – 3	φ_1	8.50-13.5	450-550	2 – 4	5 – 25
	φ_2				
	φ_3				
	φ_4				
Set – 4	φ_1	9.50-16.5	450-550	2 – 4	5 – 25
	φ_2				
	φ_3				
	φ_4				

B6.0 RESULTS AND INFERENCE

A comprehensive summary of the average data that includes all the operating parameters from the representative experiment matrix in Table B-2, along with laminar flame speeds (S_L) and stretch rates (α) for all the seven test fuels are listed in Appendices B-1 to B-7. This section will present the summary of results based on flame speeds, total and extinction stretch rates, along with important significant conclusions.

B6.1 Laminar Flame Speeds

The measured laminar flame speed is modeled according to equation 4 and the constants were determined such that the root-mean-square of the difference between computed and measured flame speeds were insignificant. Figure B-5 shows the degree of correlation between measured and modeled flame speed values. The constants in equation 4 for all the seven test fuels are listed in Table B-3. These constants will be used to generate plots for flame speed for varying temperatures, pressures and equivalence ratios for all the test fuels.

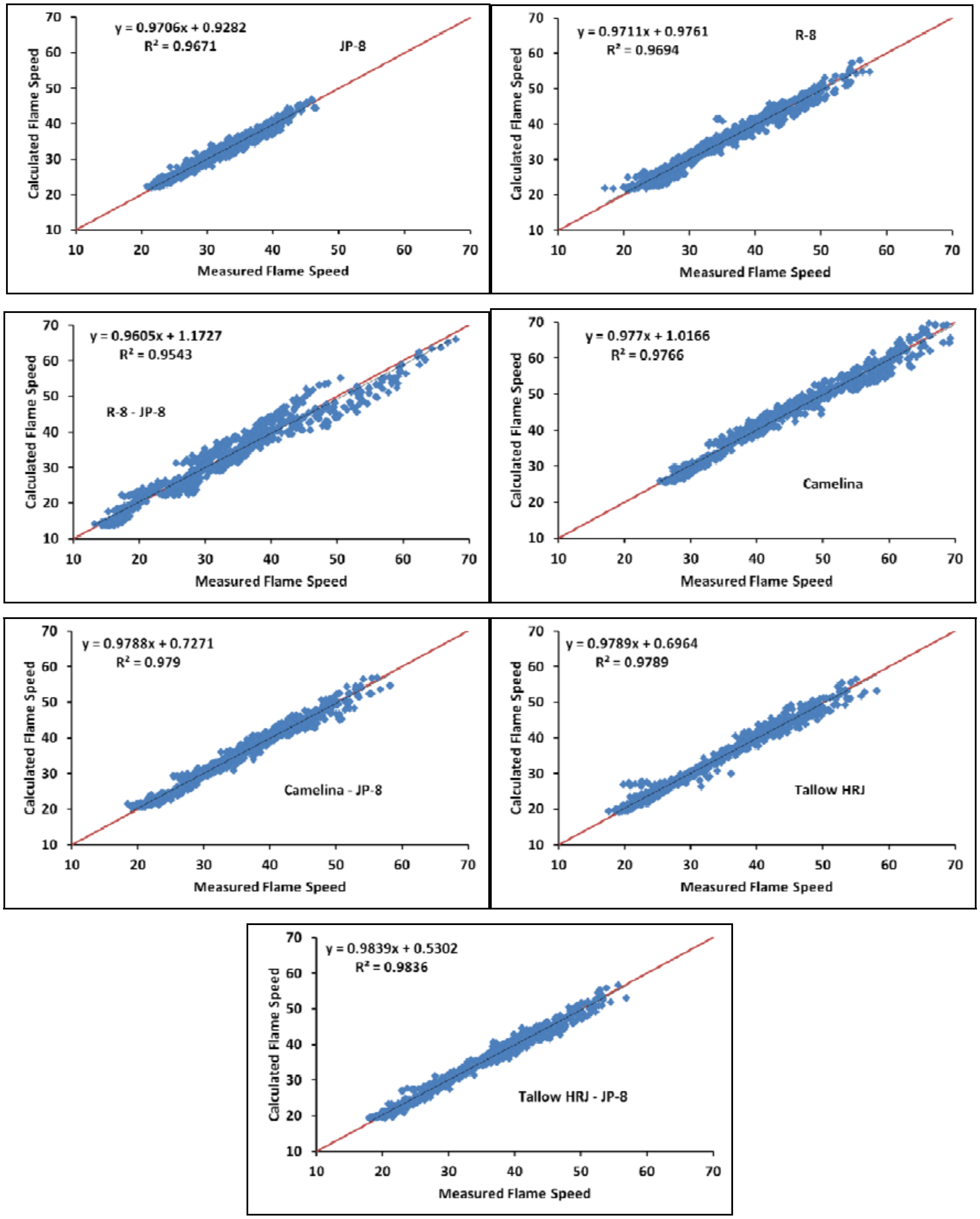

Figure B-5. Degree of Correlation between Measured and Modeled Flame Speed Data

Table B-3. Flame Speed Model Constants

Constants	JP-8	R8	R8-JP-8	Camelina	Camelina-JP-8	Tallow	Tallow-JP-8
K_1	44.1764	52.2552	53.7884	73.1249	56.3789	53.8830	55.0878
K_2	-58.6514	-56.5788	-50.8256	-69.4063	-54.2450	-57.3621	-53.0223
K_3	2.9254	3.2240	4.2403	3.0760	2.8840	2.8520	2.9891
K_4	1.3060	2.8290	-2.1242	1.5736	-0.6219	-0.9026	-0.0678
K_5	-0.1846	-0.2073	-0.5282	-0.1208	-0.1557	-0.1741	-0.2000
K_6	0.9268	0.3620	1.0984	0.7328	1.0691	0.9406	0.8231
ϕ_{max}	1.3818	1.4229	1.5000	1.5000	1.5000	1.4553	1.5000
T_{ref}	500.00	500.00	500.00	500.00	500.00	500.00	500.00
P_{ref}	10.000	10.000	10.000	10.000	10.000	10.000	10.000

The equivalence ratios that were used to obtain laminar flame speeds range from 0.6 to 1.1. For purposes of discussion, the current report analyses the flame speed results for two extreme equivalence ratios, $\phi = 0.6$ and 1.1, with pressures ranging from 4.5 to 16.5 bar and temperatures ranging from 450 to 550 Kelvin, for all the seven test fuels listed in Table B-1 and Table B-3.

B6.2 Flame Extinction and Desirable Criteria for Laminar Flame Speed

In a gas turbine combustor, the velocity of air flow is an additional parameter that must be taken into account when estimating flame speeds. At high Reynolds numbers, in a practical gas turbine combustor application, the flow becomes turbulent. If u'_{rms} is the root-mean-square of the velocity fluctuations in the flow, then the turbulent flame speed for a turbulent diffusion flame is given by Karlovitz equation (equation 8).

$$S_T = S_L + u'_{rms} \tag{8}$$

At high Reynolds numbers, the turbulent flow induces flame stretch, which causes variation in local equivalence ratios within the turbulent diffusion flame. Thus, in a gas turbine combustor, flame extinction occurs when the local flow speed in the diffusion flame exceeds the turbulent flame speed. Since laminar flame speed is a component of the turbulent flame speed, based on the above argument, it is desirable to have a higher laminar flame speed for the alternative fuels and alternative fuel blends, compared to JP-8, to resist flame extinction. On the contrary, a lower laminar flame speed compared to JP-8 will enhance the chances of flame extinction in a gas turbine combustor, especially at lean-blowout operating conditions. Therefore, by examining the magnitude of laminar flame speeds, we can predict if the fuel might perform better or worse at lean-blow out conditions compared to JP-8.

B6.3 Extinction and Lean-Blowout Prediction Based on Laminar Flame Speeds

Figure B-6 and Figure B-7 show the laminar flame speed plots of R8, Camelina, Tallow HRJ and 50/50 blends of these alternative fuels with JP-8, relative to laminar flame speeds of JP-8, at equivalence ratios corresponding to 0.6 and 1.1 respectively. For Figure B-6 and Figure B-7, at $\varphi=0.6$ and 1.1, for the pressures and temperatures indicated, the overall conclusion is that the laminar flame speed is higher for all three alternative fuels and fuel blends compared to JP-8.

Comparing the alternative fuel samples, it can be concluded that Camelina has the highest overall flame speed followed by R8. Tallow HRJ has the lowest overall flame speed. However, when the 50/50 fuel blends are compared, R8–JP-8 blend has the highest range of laminar flame

speed, followed by Camelina–JP-8 blend. Tallow HRJ–JP-8 blend encompasses a less narrow range of flame speed.

The plots in Figure B-6 and Figure B-7 can be reduced to two dimensional plots, by evaluating flame speed specific pressure and temperature. The lowest operating point in the experiment matrix is chosen to study the variation of laminar flame speed with equivalence ratio. A pressure of 4.5 bar (65.3psi) and a temperature of 450 Kelvin (~350 ^{o}F) is used to obtain a plot of laminar flame speed versus equivalence ratio, as shown in Figure B-8.

The 50/50 blend of R8–JP-8 fuel has the highest laminar flame speed followed by R8 fuel, followed by JP-8. Blending R8 fuel with JP-8 increased the laminar flame speed of JP-8 beyond the level of R8. At φ=0.5, the difference in flame speed between R8 and R8–JP-8 fuel blend is not significant and the R8–JP-8 blend still has a greater laminar flame speed value compared to JP-8. Based on this inference and equation 8, it can be concluded that R8–JP-8 blend will perform better at extinction conditions compared to JP-8.

Camelina fuel has the highest laminar flame speed followed by 50/50 Camelina–JP-8 fuel blend, followed by JP-8. In this case, blending alternative fuel to JP-8 did not increase the laminar flame speed to the level of alternative fuel. At φ=0.5, Camelina–JP-8 blend has a greater laminar flame speed value compared to JP-8. Therefore, it can be concluded that Camelina–JP-8 fuel blend will perform better compared to JP-8, at flame extinction conditions.

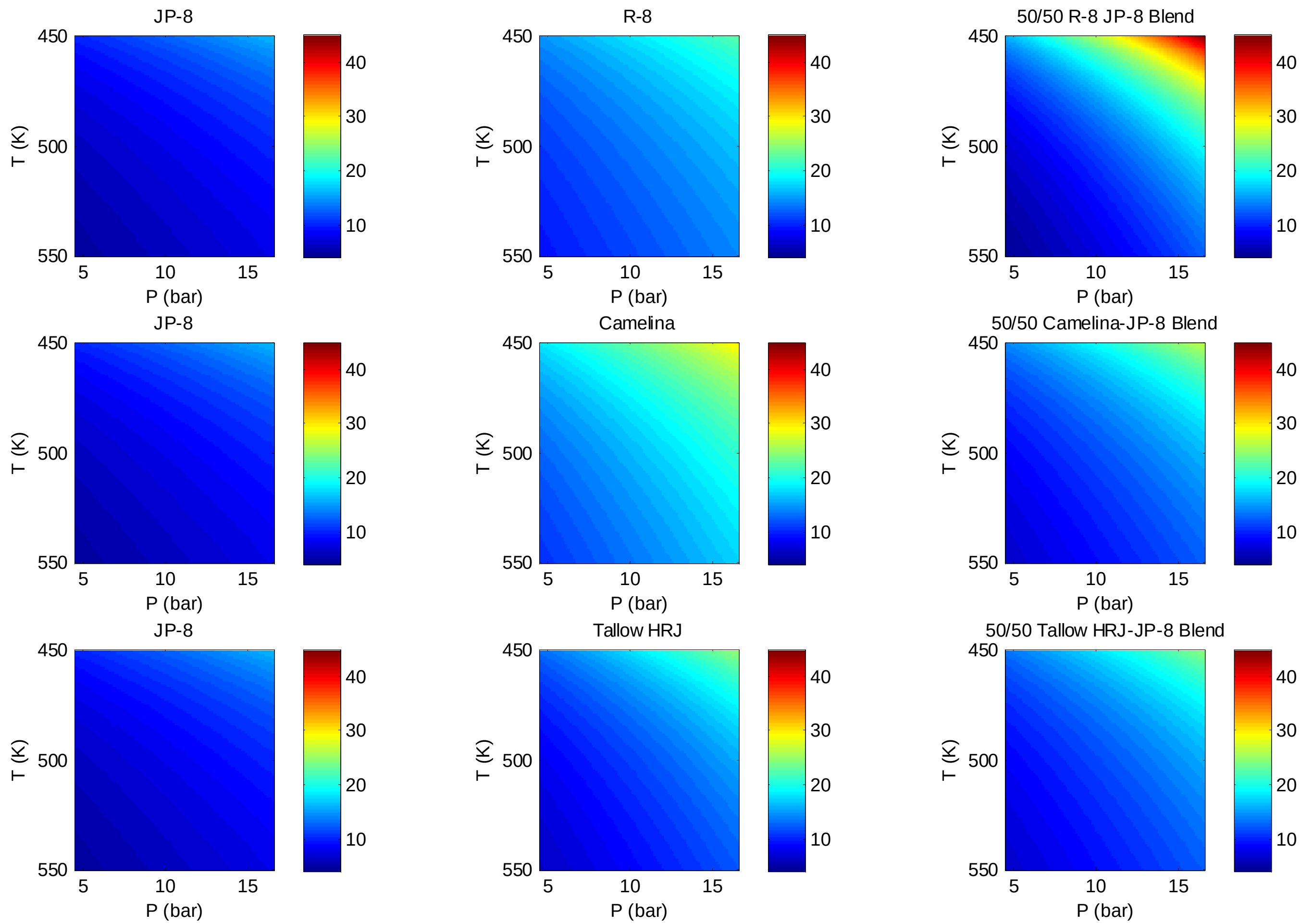

Figure B-6. Laminar Flame Speed Plots of Test Fuels at φ=0.6

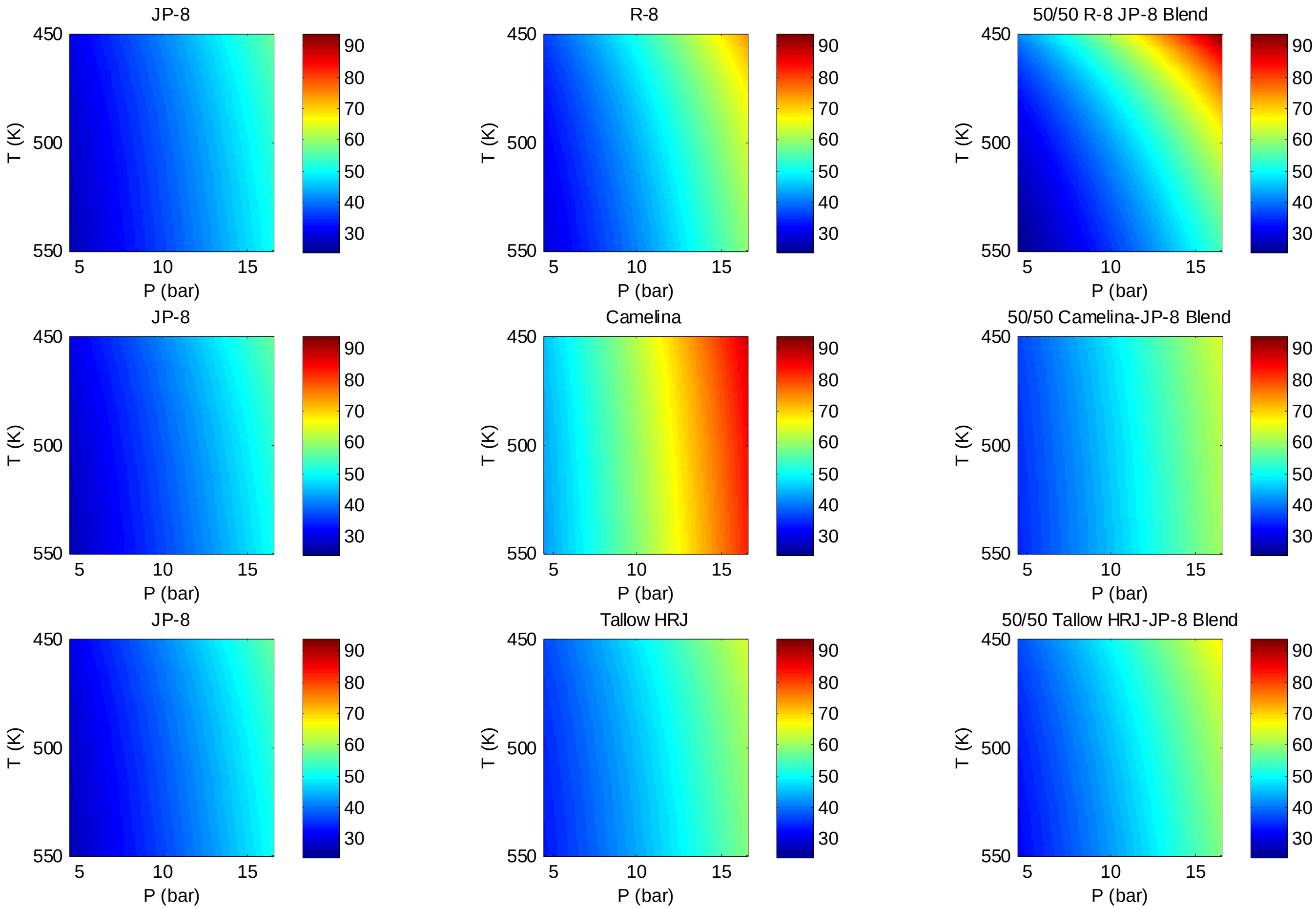

Figure B-7. Laminar Flame Speed Plots of Test Fuels at φ=1.1

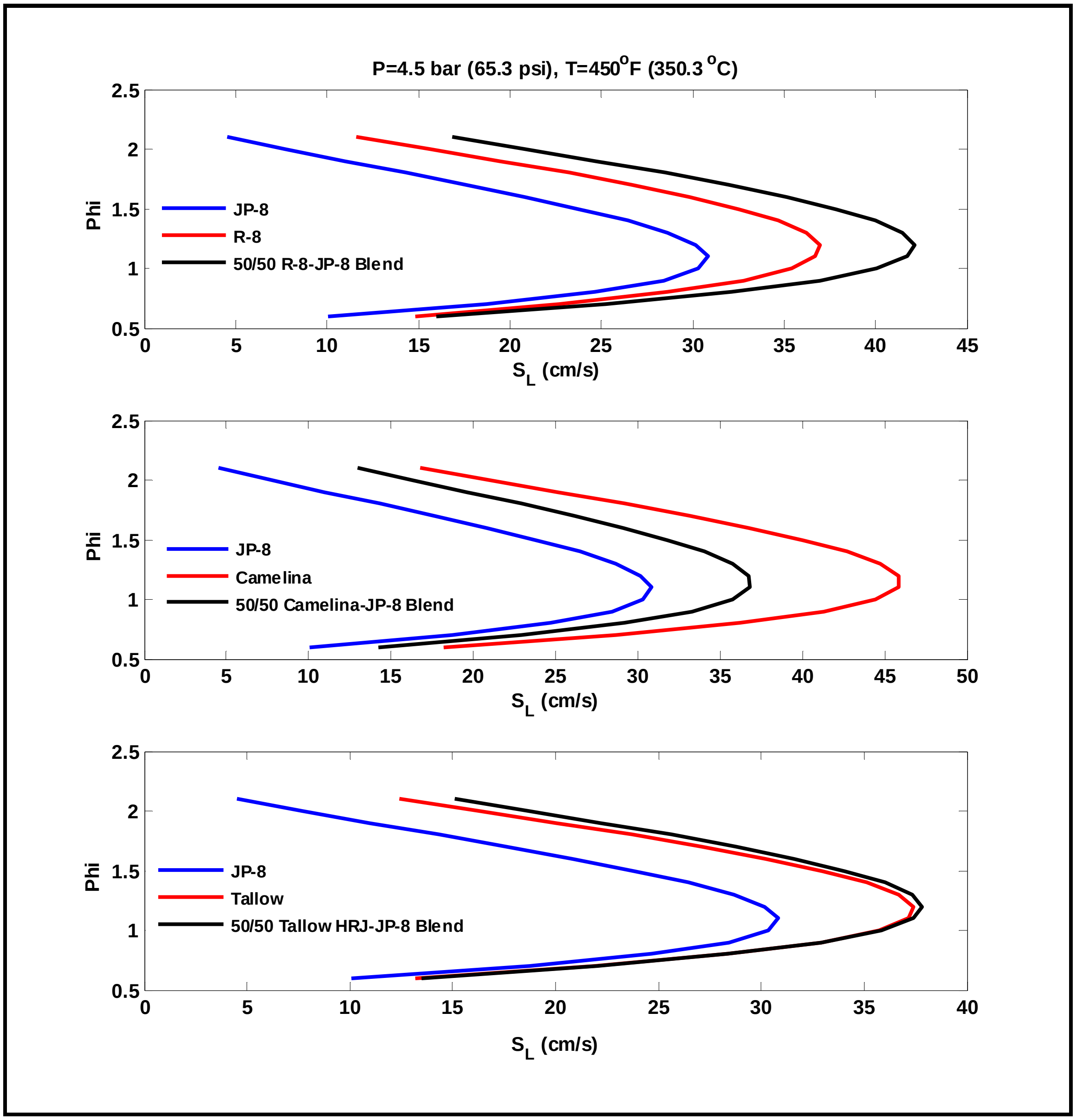

Figure B-8. Laminar Flame Speed versus Equivalence Ratio

Blending Tallow HRJ to JP-8 showed no significant increase in laminar flame speed values beyond Tallow-HRJ. Again, the 50/50 Tallow–JP-8 has a higher flame speed value compared to JP-8 and is expected to perform better when compared to JP-8 at flame extinction conditions. Based on the conclusions from all three alternative fuel blends, 50/50 R8–JP-8 fuel blend will have the highest flame speed and performs superior at flame extinction scenarios compared to JP-8, followed by 50/50 Camelina–JP-8 fuel blend and 50/50 Tallow–JP-8.

B6.4 Lean-Blow Out Prediction Based On Extinction Stretch Rates

A comparison of the extinction performance of the alternative fuel blends in Section B6.3 was completely based on laminar flame speeds relative to JP-8. In this section, the extinction performance of the alternative fuel blends will be examined based on extinction stretch rates.

Table B-4 lists the calculated extinction stretch rates as a function of equivalence ratio for all the seven test fuels. Figure B-9 shows a plot of the extinction stretch rates as a function of equivalence ratio comparing JP-8 to each alternative fuel and its corresponding 50/50 fuel blend, for P = 4.50 to 7.50 bar. Since flame extinction at lean-blow out conditions occur at lower pressures, Figure B-9 shows plots corresponding to pressures from 4.50 to 7.50 bar.

Table B-4. Summary of Extinction Stretch Rates of Test Fuels

P - bar	JP-8		R8		50/50 R8–JP-8 Blend		Camelina		50/50 Camelina–JP-8 Blend		Tallow		50/50 Tallow–JP-8 Blend	
	Φ	α (1/s)	Φ	α (1/s)	Φ	α (1/s)	Φ	α (1/s)	Φ	α (1/s)	Φ	α (1/s)	Φ	α (1/s)
4.50-7.50	0.82	207.3	0.69	146.8	0.65	184.3	0.64	186.5	0.71	180.5	0.70	150.8	0.70	161.8
	0.86	224.1	0.80	240.9	0.76	268.7	0.80	259.8	0.81	224.8	0.80	241.2	0.80	244.6
	0.91	250.4	0.90	353.7	0.83	346.0	0.84	277.5	0.90	342.7	0.90	313.3	0.90	297.0
	0.95	300.0	1.00	303.4	0.95	375.9	0.94	272.2	1.01	324.1	1.00	354.2	1.00	343.9
	1.00	246.9					0.99	177.5						
6.00-10.5	0.79	179.3	0.69	138.8	0.66	110.1	0.72	215.6	0.70	168.4	0.70	147.6	0.70	147.5
	0.84	212.4	0.80	236.1	0.76	209.7	0.81	293.7	0.80	250.2	0.80	222.2	0.81	232.7
	0.89	242.3	0.91	302.2	0.85	270.2	0.90	379.5	0.90	282.0	0.90	285.8	0.90	299.7
	0.94	308.2	1.01	221.7	0.95	305.5	1.00	336.2	0.99	230.2	1.00	238.8	0.99	259.8
	1.00	209.0												
8.50-13.5	0.81	150.7	0.71	166.3	0.65	105.8			0.69	125.0	0.70	135.7	0.70	151.7
	0.86	225.7	0.81	249.7	0.75	196.2			0.81	249.5	0.80	224.4	0.81	234.5
	0.91	272.8	0.90	296.5	0.86	266.1			0.91	274.9	0.90	274.3	0.90	304.3
	0.96	245.8	1.00	238.6	0.94	256.4			1.01	244.7	1.01	222.8	1.01	225.9
	1.01	192.4												
9.50-16.5	0.81	175.2	0.72	178.3	0.63	97.20	0.69	212.2	0.71	146.3	0.70	113.8	0.70	144.9
	0.86	208.3	0.83	237.1	0.74	215.7	0.80	300.2	0.81	218.0	0.80	143.4	0.81	207.7
	0.91	240.1	0.91	234.7	0.85	259.6	0.90	336.8	0.91	243.2	0.90	234.0	0.91	229.3
	0.96	188.3	0.99	210.6	0.95	215.5	1.00	296.3	1.01	237.2	1.01	214.0	1.01	228.0
	1.00	184.2	1.00	303.4										

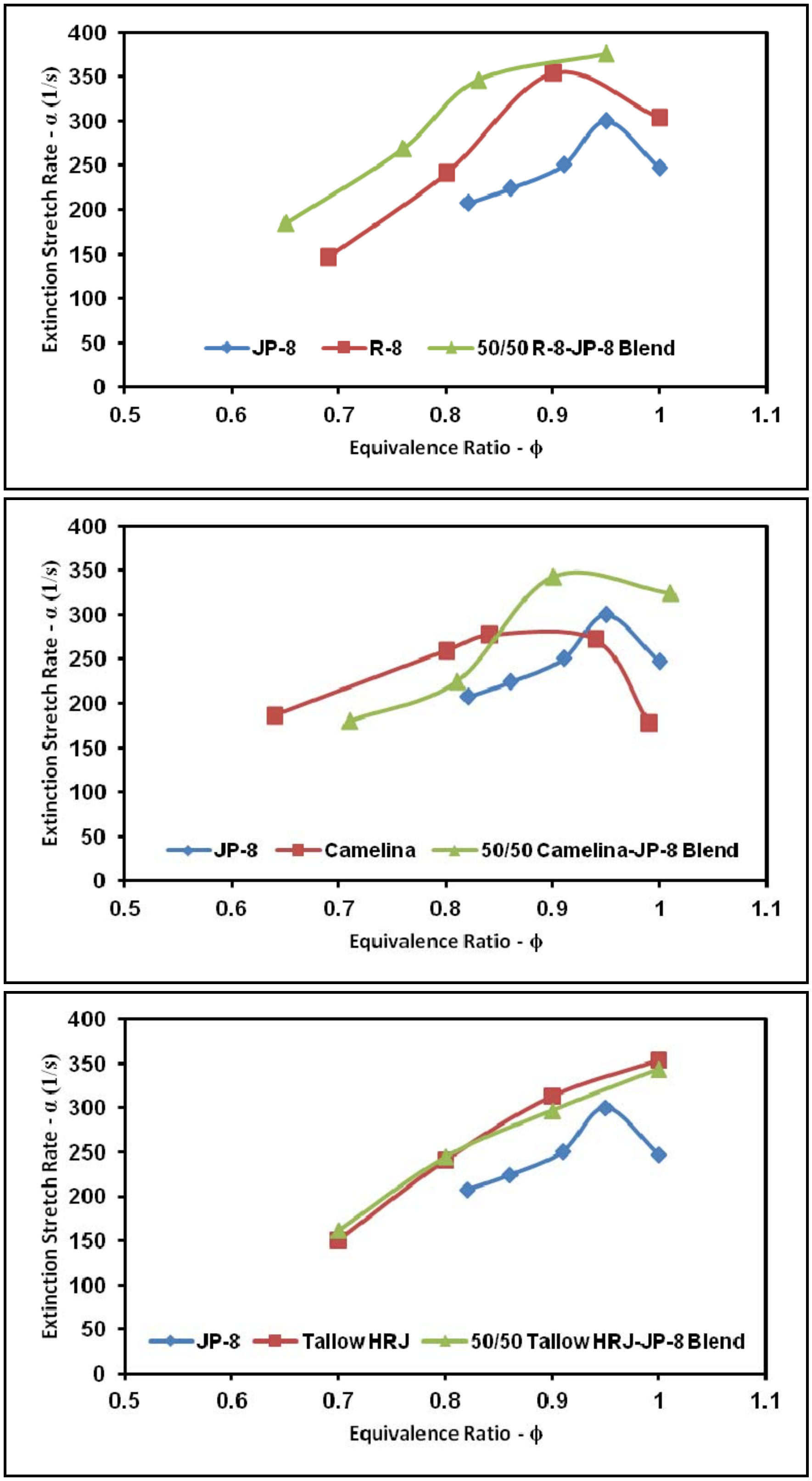

Figure B-9. Extinction Stretch Rates of Test Fuels at P = 4.50-7.50 bar

The extinction stretch rate results in Figure B-9 are consistent with laminar flame speed curves in Figure B-8. R8 fuel has higher resistance to extinction is higher compared to JP-8 fuel. Blending R8 to JP-8 increases the resistance to extinction beyond the extinction stretch rate of R8. It should also be noted that the extinction stretch rate curves for 50/50 R8–JP-8 fuel blend and R8 fuel are nearly parallel and difference in extinction stretch rate is markedly higher. Based on this trend, it can be predicted that 50/50 R8–JP-8 fuel blend will be highly resistant to extinction at near lean-blowout conditions.

Camelina shows an overlapping trend with JP-8 fuel. However, a 50/50 Camelina–JP-8 blend shows a clear separation from the JP-8 extinction stretch rate curve at higher equivalence ratios. Based on these trends, for lower equivalence ratios, it should be noted that the difference in extinction stretch rate of 50/50 Camelina–JP-8 blend is only slightly greater than JP-8. It can be concluded that blending Camelina to JP-8 increases the resistance to extinction marginally and that for all practical purposes, at lean-blowout scenarios, the resistance to extinction can be considered to be of the same magnitude.

Tallow HRJ has significantly higher resistance to extinction compared to JP-8. However, the extinction stretch rate curves for 50/50 Tallow HRJ–JP-8 and Tallow HRJ fuel are nearly identical. This indicates that the resistance to extinction does not increase beyond the level of Tallow-HRJ. It can also be concluded that addition of JP-8 only fulfills the aromatic content requirement in Tallow-HRJ and does not contribute to increase in resistance to flame extinction. Since the extinction stretch rate curves for the Tallow- HRJ fuel blend with JP-8, will get closer to each other for lower equivalence ratios, it can be concluded that 50/50 Tallow HRJ–JP-8 blend will have nearly the same level of extinction stretch rate at lean-blow out conditions.

B7.0 SUMMARY OF CONCLUSIONS

In summary, considering the totality of laminar flame speeds and extinction stretch rates, and comparing the alternative fuel blends with JP-8, it can be concluded that 50/50 R8–JP-8 fuel blend will have higher resistance to flame extinction at lean-blow-out conditions in a gas turbine combustor compared to 50/50 Camelina–JP-8 blend and 50/50 Tallow HRJ–JP-8, which is predicted to have the same level of resistance to flame extinction as JP-8 fuel. Further research on flame resistance and fuel chemistry is beyond the scope of this work and is highly recommended for future research. The conclusions on laminar flame speeds, extinction stretch rates and resistance to flame extinction is summarized in Table B-5.

Table B-5. Summary of Conclusions

Fuel Blend	Comparison of Characteristics relative to JP-8		
	Flame Speed	**Extinction Stretch Rate at Low Equivalence Ratio**	**Resistance to Flame Extinction at Lean-Blowout Condition**
50/50 R8–JP-8 Fuel Blend	Significantly higher	Significantly higher	Significantly higher than JP-8
50/50 Camelina–JP-8 Fuel Blend	Marginally higher	Difference not significant	Same as JP-8 for all practical purposes
50/50 HRJ Tallow–JP-8 Fuel Blend	Marginally higher	Nearly the same	Same as JP-8 for all practical purposes

B8.0 RECOMMENDATIONS FOR FUTURE RESEARCH

The above conclusions on flame extinction at lean-blowout conditions were predictions based on laminar flame speeds and extinction stretch rates measured at higher equivalence ratios in a constant volume combustion chamber. Further experiments have to be done with turbulent diffusion flames, laser and optical diagnostics to measure the actual flame speed at low equivalence ratios rather than prediction based on extrapolating trends. Further research is recommended to investigate the role of boiling point distribution and fuel chemistry (aromatics), if any, in resistance to flame extinction at lean-blow out conditions in a gas turbine combustor.

B9.0 ACRONYMS & ABBREVIATIONS

Acronym	Description
°	Degree
%	Percent
HRJ	Hydroprocessed Renewable Jet
LBO	Lean-Blowout
SwRI	Southwest Research Institute

Appendix B-1 - JP-8 Flame Speed Data

DATA SET – I									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [K]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Stretch Rate [1/s]**	**Flame Speed [cm/sec]**	**(dr/dt)**
0.03101	0.815	4.67	477.04	28.41	3.05	2216.58	76.49	28.41	116.62
0.03201	0.815	4.75	479.12	28.79	3.18	2218.03	73.35	28.79	
0.03301	0.815	4.84	481.27	27.75	3.30	2219.61	70.62	27.75	
0.03401	0.815	4.94	483.73	29.46	3.43	2221.27	67.98	29.46	
0.03501	0.815	5.05	486.40	29.76	3.56	2223.15	65.56	29.76	
0.03601	0.815	5.17	489.33	30.60	3.68	2225.20	63.30	30.60	
0.03701	0.815	5.30	492.46	30.71	3.81	2227.44	61.24	30.71	
0.03801	0.815	5.45	495.75	30.44	3.93	2229.83	59.38	30.44	
0.03901	0.815	5.60	499.26	30.75	4.04	2232.35	57.66	30.75	
0.04001	0.815	5.78	503.06	31.55	4.16	2235.04	56.04	31.55	
0.04101	0.815	5.96	507.03	31.38	4.27	2237.94	54.57	31.38	
0.04201	0.815	6.16	511.26	31.93	4.38	2240.98	53.19	31.93	
0.04301	0.815	6.39	515.86	33.19	4.50	2244.23	51.88	33.19	
0.04401	0.815	6.64	520.76	33.83	4.60	2247.76	50.65	33.83	
0.04501	0.815	6.91	525.83	33.65	4.71	2251.51	49.53	33.65	
0.04601	0.815	7.19	531.09	33.59	4.81	2255.40	48.50	33.59	
0.04701	0.815	7.50	536.63	34.11	4.91	2259.44	47.54	34.11	
0.02801	0.86	4.77	477.76	31.94	3.16	2280.42	80.55	31.94	127.41
0.02901	0.86	4.86	480.14	29.72	3.30	2282.20	77.20	29.72	
0.03001	0.86	4.97	482.83	30.92	3.44	2284.03	74.08	30.92	
0.03101	0.86	5.10	485.87	32.53	3.58	2286.09	71.13	32.53	
0.03201	0.86	5.24	489.14	32.44	3.72	2288.42	68.49	32.44	
0.03301	0.86	5.40	492.68	32.80	3.86	2290.91	66.08	32.80	
0.03401	0.86	5.56	496.42	32.59	3.99	2293.60	63.92	32.59	
0.03501	0.86	5.75	500.55	33.90	4.12	2296.47	61.88	33.90	
0.03601	0.86	5.96	504.91	33.84	4.24	2299.62	60.04	33.84	
0.03701	0.86	6.18	509.49	33.71	4.37	2302.94	58.37	33.71	
0.03801	0.86	6.43	514.54	35.40	4.49	2306.45	56.78	35.40	
0.03901	0.86	6.71	519.88	35.69	4.61	2310.31	55.32	35.69	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.04001	0.86	7.00	525.48	35.81	4.72	2314.38	53.98	35.81	
0.04101	0.86	7.33	531.30	35.73	4.83	2318.65	52.77	35.73	
0.04201	0.86	7.69	537.65	37.48	4.94	2323.12	51.60	37.48	
0.02401	0.909	4.69	476.73	32.84	3.08	2340.30	93.44	32.84	143.75
0.02501	0.909	4.80	479.41	33.60	3.24	2342.13	88.76	33.60	
0.02601	0.909	4.92	482.30	33.26	3.40	2344.18	84.68	33.26	
0.02701	0.909	5.06	485.63	35.02	3.55	2346.43	80.87	35.02	
0.02801	0.909	5.21	489.27	35.24	3.71	2348.99	77.48	35.24	
0.02901	0.909	5.38	493.22	35.54	3.86	2351.78	74.44	35.54	
0.03001	0.909	5.57	497.46	35.55	4.01	2354.80	71.72	35.55	
0.03101	0.909	5.79	502.17	36.92	4.15	2358.07	69.20	36.92	
0.03201	0.909	6.03	507.10	36.44	4.29	2361.66	66.97	36.44	
0.03301	0.909	6.30	512.57	38.07	4.43	2365.46	64.88	38.07	
0.03401	0.909	6.59	518.41	38.59	4.57	2369.64	62.97	38.59	
0.03501	0.909	6.93	524.69	39.38	4.70	2374.11	61.23	39.38	
0.03601	0.909	7.29	531.25	39.30	4.82	2378.89	59.66	39.30	
0.03701	0.909	7.69	538.23	40.04	4.94	2383.90	58.21	40.04	
0.02201	0.954	4.69	477.03	36.09	3.06	2385.84	102.66	36.09	157.29
0.02301	0.954	4.81	479.98	36.25	3.24	2387.90	96.96	36.25	
0.02401	0.954	4.94	483.11	34.84	3.41	2390.18	92.21	34.84	
0.02501	0.954	5.10	486.87	38.02	3.59	2392.67	87.66	38.02	
0.02601	0.954	5.28	491.04	38.61	3.76	2395.60	83.62	38.61	
0.02701	0.954	5.47	495.37	36.98	3.92	2398.79	80.22	36.98	
0.02801	0.954	5.70	500.37	39.61	4.09	2402.20	77.00	39.61	
0.02901	0.954	5.95	505.62	38.88	4.24	2406.03	74.21	38.88	
0.03001	0.954	6.23	511.38	39.92	4.39	2410.10	71.66	39.92	
0.03101	0.954	6.55	517.71	41.42	4.54	2414.56	69.31	41.42	
0.03201	0.954	6.91	524.48	41.82	4.68	2419.43	67.20	41.82	
0.03301	0.954	7.30	531.54	41.47	4.81	2424.59	65.34	41.47	
0.03401	0.954	7.74	539.08	42.26	4.94	2430.02	63.64	42.26	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.02101	0.999	4.72	477.86	36.59	3.11	2610.95	107.61	36.59	167.11
0.02201	0.999	4.85	481.01	35.40	3.29	2610.93	101.58	35.40	
0.02301	0.999	5.00	484.69	37.39	3.48	2610.92	96.11	37.39	
0.02401	0.999	5.18	488.90	39.03	3.67	2610.90	91.19	39.03	
0.02501	0.999	5.38	493.48	38.93	3.84	2610.87	86.95	38.93	
0.02601	0.999	5.61	498.53	39.83	4.02	2610.85	83.19	39.83	
0.02701	0.999	5.87	503.96	40.06	4.18	2610.82	79.89	40.06	
0.02801	0.999	6.16	509.93	41.34	4.35	2610.80	76.91	41.34	
0.02901	0.999	6.48	516.34	41.90	4.50	2610.77	74.26	41.90	
0.03001	0.999	6.86	523.42	44.04	4.65	2610.73	71.81	44.04	
0.03101	0.999	7.27	530.88	44.32	4.80	2610.70	69.65	44.32	
0.03201	0.999	7.74	538.85	45.45	4.94	2610.66	67.69	45.45	
0.02101	0.999	4.72	478.71	34.46	3.11	2610.94	107.40	34.46	
0.02201	0.999	4.85	481.95	36.29	3.30	2610.93	101.27	36.29	
0.02301	0.999	5.01	485.66	37.46	3.49	2610.91	95.83	37.46	
0.02401	0.999	5.19	489.82	38.44	3.67	2610.89	91.03	38.44	
0.02501	0.999	5.39	494.36	38.56	3.85	2610.87	86.86	38.56	
0.02601	0.999	5.61	499.41	39.82	4.02	2610.85	83.11	39.82	
0.02701	0.999	5.87	504.95	40.76	4.19	2610.82	79.77	40.76	
0.02801	0.999	6.17	510.92	41.26	4.35	2610.79	76.82	41.26	
0.02901	0.999	6.50	517.46	42.77	4.51	2610.76	74.13	42.77	
0.03001	0.999	6.88	524.60	44.30	4.66	2610.73	71.69	44.30	
0.03101	0.999	7.29	532.01	43.92	4.80	2610.69	69.56	43.92	
0.03201	0.999	7.76	540.07	45.90	4.94	2610.65	67.60	45.90	

DATA SET - II									
0.03601	0.788	6.41	477.50	23.81	3.12	2178.28	60.87	23.81	94.93
0.03701	0.788	6.50	479.33	25.01	3.23	2179.53	58.80	25.01	
0.03801	0.788	6.61	481.21	24.25	3.33	2180.93	56.96	24.25	
0.03901	0.788	6.72	483.30	25.35	3.44	2182.38	55.18	25.35	
0.04001	0.788	6.84	485.42	24.30	3.54	2183.98	53.60	24.30	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.04101	0.788	6.97	487.72	24.93	3.64	2185.61	52.11	24.93	
0.04201	0.788	7.11	490.16	25.19	3.74	2187.37	50.71	25.19	
0.04301	0.788	7.26	492.80	25.92	3.85	2189.26	49.37	25.92	
0.04401	0.788	7.43	495.53	25.54	3.94	2191.28	48.15	25.54	
0.04501	0.788	7.60	498.37	25.32	4.04	2193.38	47.02	25.32	
0.04601	0.788	7.79	501.48	26.63	4.13	2195.57	45.92	26.63	
0.04701	0.788	7.99	504.74	26.73	4.23	2197.96	44.89	26.73	
0.04801	0.788	8.22	508.23	27.52	4.32	2200.48	43.90	27.52	
0.04901	0.788	8.45	511.76	26.78	4.41	2203.16	43.01	26.78	
0.05001	0.788	8.70	515.43	26.85	4.50	2205.88	42.17	26.85	
0.05101	0.788	8.96	519.28	27.21	4.59	2208.72	41.38	27.21	
0.05201	0.788	9.25	523.36	27.84	4.67	2211.69	40.62	27.84	
0.05301	0.788	9.55	527.60	28.13	4.76	2214.84	39.91	28.13	
0.05401	0.788	9.88	532.01	28.30	4.84	2218.12	39.23	28.30	
0.05501	0.788	10.23	536.62	28.78	4.92	2221.53	38.59	28.78	
0.02901	0.844	6.33	476.37	25.32	3.02	2261.14	75.31	25.32	113.81
0.03001	0.844	6.44	478.46	28.64	3.16	2262.46	72.13	28.64	
0.03101	0.844	6.57	480.76	29.15	3.29	2264.06	69.21	29.15	
0.03201	0.844	6.70	483.17	28.43	3.42	2265.81	66.64	28.43	
0.03301	0.844	6.85	485.77	28.69	3.54	2267.65	64.29	28.69	
0.03401	0.844	7.00	488.51	28.23	3.66	2269.64	62.19	28.23	
0.03501	0.844	7.18	491.52	29.25	3.78	2271.74	60.19	29.25	
0.03601	0.844	7.37	494.72	29.35	3.90	2274.04	58.37	29.35	
0.03701	0.844	7.57	498.10	29.30	4.01	2276.48	56.70	29.30	
0.03801	0.844	7.80	501.80	30.51	4.13	2279.08	55.10	30.51	
0.03901	0.844	8.05	505.73	30.77	4.24	2281.91	53.63	30.77	
0.04001	0.844	8.33	509.97	31.59	4.36	2284.93	52.25	31.59	
0.04101	0.844	8.61	514.17	29.99	4.46	2288.14	51.04	29.99	
0.04201	0.844	8.92	518.77	31.51	4.56	2291.37	49.86	31.51	
0.04301	0.844	9.26	523.58	31.69	4.67	2294.90	48.78	31.69	
0.04401	0.844	9.63	528.68	32.30	4.77	2298.59	47.76	32.30	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.04501	0.844	10.03	533.98	32.43	4.86	2302.49	46.81	32.43	
0.04601	0.844	10.47	539.59	33.19	4.96	2306.56	45.92	33.19	
0.02601	0.89	6.44	478.35	30.39	3.14	2323.98	82.16	30.39	129.10
0.02701	0.89	6.58	480.91	31.46	3.29	2325.73	78.46	31.46	
0.02801	0.89	6.74	483.72	31.84	3.44	2327.69	75.11	31.84	
0.02901	0.89	6.91	486.81	32.24	3.58	2329.85	72.09	32.24	
0.03001	0.89	7.10	490.05	31.57	3.72	2332.20	69.43	31.57	
0.03101	0.89	7.31	493.70	33.16	3.86	2334.71	66.92	33.16	
0.03201	0.89	7.54	497.45	31.93	3.99	2337.48	64.74	31.93	
0.03301	0.89	7.80	501.67	33.89	4.12	2340.37	62.64	33.89	
0.03401	0.89	8.09	506.20	34.33	4.25	2343.60	60.72	34.33	
0.03501	0.89	8.41	510.94	34.06	4.38	2347.05	58.99	34.06	
0.03601	0.89	8.74	515.91	34.00	4.50	2350.67	57.43	34.00	
0.03701	0.89	9.12	521.29	35.08	4.61	2354.49	55.96	35.08	
0.03801	0.89	9.54	526.98	35.51	4.73	2358.60	54.60	35.51	
0.03901	0.89	9.99	532.95	35.80	4.84	2362.95	53.36	35.80	
0.04001	0.89	10.49	539.39	37.13	4.95	2367.53	52.18	37.13	
0.02401	0.944	6.47	479.13	34.31	3.18	2385.18	89.93	34.31	142.90
0.02501	0.944	6.64	482.07	34.03	3.34	2387.26	85.50	34.03	
0.02601	0.944	6.82	485.28	34.09	3.50	2389.54	81.59	34.09	
0.02701	0.944	7.02	488.74	33.82	3.66	2392.02	78.16	33.82	
0.02801	0.944	7.25	492.66	35.34	3.81	2394.72	74.97	35.34	
0.02901	0.944	7.50	496.71	34.07	3.96	2397.71	72.23	34.07	
0.03001	0.944	7.78	501.26	35.79	4.10	2400.87	69.65	35.79	
0.03101	0.944	8.10	506.25	36.78	4.25	2404.39	67.28	36.78	
0.03201	0.944	8.45	511.56	36.93	4.39	2408.23	65.15	36.93	
0.03301	0.944	8.83	517.06	36.23	4.52	2412.28	63.28	36.23	
0.03401	0.944	9.27	523.11	37.91	4.65	2416.54	61.51	37.91	
0.03501	0.944	9.73	529.42	37.69	4.77	2421.17	59.92	37.69	
0.03601	0.944	10.26	536.26	39.07	4.89	2426.04	58.43	39.07	
0.02201	0.999	6.41	478.29	31.83	3.10	2610.94	100.05	31.83	154.86

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.02301	0.999	6.58	481.34	34.64	3.28	2610.93	94.55	34.64	
0.02401	0.999	6.77	484.70	34.68	3.45	2610.91	89.79	34.68	
0.02501	0.999	6.98	488.29	34.04	3.61	2610.90	85.71	34.04	
0.02601	0.999	7.22	492.49	36.80	3.78	2610.88	81.84	36.80	
0.02701	0.999	7.49	496.83	35.43	3.94	2610.86	78.58	35.43	
0.02801	0.999	7.80	501.74	37.40	4.10	2610.83	75.55	37.40	
0.02901	0.999	8.15	507.10	38.49	4.25	2610.81	72.79	38.49	
0.03001	0.999	8.53	512.78	38.52	4.40	2610.78	70.36	38.52	
0.03101	0.999	8.96	518.94	39.71	4.55	2610.75	68.13	39.71	
0.03201	0.999	9.44	525.54	40.68	4.68	2610.72	66.11	40.68	
0.03301	0.999	9.98	532.67	42.03	4.82	2610.69	64.26	42.03	
0.03401	0.999	10.63	540.72	45.72	4.96	2610.65	62.47	45.72	
DATA SET – III									
0.03601	0.808	9.75	476.99	22.22	3.05	2211.74	57.38	22.22	87.37
0.03701	0.808	9.88	478.56	22.30	3.15	2212.87	55.55	22.30	
0.03801	0.808	10.01	480.19	21.76	3.24	2214.07	53.90	21.76	
0.03901	0.808	10.16	481.94	22.05	3.34	2215.32	52.35	22.05	
0.04001	0.808	10.32	483.86	22.89	3.44	2216.67	50.85	22.89	
0.04101	0.808	10.49	485.82	22.28	3.53	2218.14	49.50	22.28	
0.04201	0.808	10.67	487.93	22.70	3.62	2219.65	48.21	22.70	
0.04301	0.808	10.87	490.17	23.03	3.72	2221.27	47.00	23.03	
0.04401	0.808	11.09	492.59	23.73	3.81	2222.99	45.83	23.73	
0.04501	0.808	11.32	495.13	23.71	3.91	2224.85	44.74	23.71	
0.04601	0.808	11.56	497.75	23.48	4.00	2226.80	43.74	23.48	
0.04701	0.808	11.81	500.48	23.48	4.08	2228.81	42.80	23.48	
0.04801	0.808	12.09	503.36	23.89	4.17	2230.91	41.91	23.89	
0.04901	0.808	12.38	506.37	23.98	4.26	2233.14	41.06	23.98	
0.05001	0.808	12.69	509.50	24.08	4.34	2235.45	40.27	24.08	
0.05101	0.808	13.03	512.80	24.44	4.42	2237.87	39.52	24.44	
0.05201	0.808	13.39	516.30	25.15	4.51	2240.41	38.79	25.15	
0.05301	0.808	13.77	519.88	24.89	4.59	2243.11	38.11	24.89	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.05401	0.808	14.17	523.59	24.98	4.66	2245.87	37.47	24.98	
0.05501	0.808	14.59	527.38	24.83	4.74	2248.73	36.88	24.83	
0.05601	0.808	15.04	531.38	25.49	4.81	2251.67	36.30	25.49	
0.05701	0.808	15.53	535.58	26.01	4.89	2254.76	35.75	26.01	
0.05801	0.808	16.05	539.94	26.30	4.96	2258.01	35.23	26.30	
0.03101	0.856	9.80	478.10	25.31	3.08	2283.71	66.30	25.31	102.18
0.03201	0.856	9.96	479.95	24.52	3.20	2285.06	63.94	24.52	
0.03301	0.856	10.13	481.97	25.10	3.31	2286.48	61.73	25.10	
0.03401	0.856	10.31	484.17	25.48	3.42	2288.04	59.68	25.48	
0.03501	0.856	10.51	486.48	25.22	3.53	2289.71	57.81	25.22	
0.03601	0.856	10.73	488.99	25.89	3.65	2291.49	56.06	25.89	
0.03701	0.856	10.97	491.72	26.55	3.76	2293.41	54.40	26.55	
0.03801	0.856	11.24	494.64	26.86	3.87	2295.51	52.85	26.86	
0.03901	0.856	11.52	497.64	26.28	3.97	2297.73	51.46	26.28	
0.04001	0.856	11.81	500.78	26.24	4.07	2300.03	50.17	26.24	
0.04101	0.856	12.14	504.18	27.12	4.18	2302.44	48.94	27.12	
0.04201	0.856	12.49	507.73	27.12	4.27	2305.04	47.80	27.12	
0.04301	0.856	12.87	511.47	27.34	4.37	2307.77	46.74	27.34	
0.04401	0.856	13.27	515.41	27.78	4.47	2310.63	45.74	27.78	
0.04501	0.856	13.71	519.56	28.09	4.56	2313.66	44.79	28.09	
0.04601	0.856	14.18	523.88	28.28	4.65	2316.84	43.91	28.28	
0.04701	0.856	14.68	528.34	28.13	4.74	2320.16	43.10	28.13	
0.04801	0.856	15.22	533.02	28.65	4.83	2323.58	42.32	28.65	
0.04901	0.856	15.81	538.02	29.69	4.91	2327.19	41.58	29.69	
0.02701	0.907	9.77	478.14	27.56	3.05	2351.53	76.46	27.56	116.69
0.02801	0.907	9.95	480.25	27.24	3.18	2353.04	73.30	27.24	
0.02901	0.907	10.15	482.61	28.28	3.32	2354.67	70.35	28.28	
0.03001	0.907	10.36	485.13	27.99	3.45	2356.48	67.71	27.99	
0.03101	0.907	10.59	487.78	27.51	3.57	2358.41	65.36	27.51	
0.03201	0.907	10.86	490.78	29.05	3.70	2360.46	63.11	29.05	
0.03301	0.907	11.15	494.01	29.49	3.82	2362.76	61.03	29.49	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.03401	0.907	11.47	497.43	29.30	3.95	2365.24	59.15	29.30	
0.03501	0.907	11.81	501.00	29.07	4.06	2367.85	57.45	29.07	
0.03601	0.907	12.18	504.89	29.99	4.18	2370.60	55.84	29.99	
0.03701	0.907	12.59	508.99	30.03	4.29	2373.58	54.36	30.03	
0.03801	0.907	13.03	513.26	29.92	4.40	2376.71	53.02	29.92	
0.03901	0.907	13.51	517.84	30.76	4.51	2380.00	51.75	30.76	
0.04001	0.907	14.03	522.66	30.94	4.62	2383.51	50.57	30.94	
0.04101	0.907	14.59	527.72	31.30	4.72	2387.20	49.48	31.30	
0.04201	0.907	15.21	533.06	31.78	4.82	2391.09	48.45	31.78	
0.04301	0.907	15.89	538.75	32.70	4.91	2395.19	47.49	32.70	
0.02501	0.957	9.84	479.36	29.62	3.10	2407.19	84.28	29.62	130.68
0.02601	0.957	10.05	481.78	29.40	3.25	2408.93	80.52	29.40	
0.02701	0.957	10.28	484.49	30.28	3.39	2410.82	77.07	30.28	
0.02801	0.957	10.53	487.37	29.75	3.53	2412.91	74.03	29.75	
0.02901	0.957	10.82	490.63	31.26	3.67	2415.17	71.16	31.26	
0.03001	0.957	11.14	494.13	31.30	3.81	2417.70	68.58	31.30	
0.03101	0.957	11.49	497.87	31.36	3.94	2420.41	66.25	31.36	
0.03201	0.957	11.86	501.84	31.23	4.07	2423.29	64.16	31.23	
0.03301	0.957	12.29	506.18	32.31	4.20	2426.37	62.19	32.31	
0.03401	0.957	12.75	510.78	32.46	4.33	2429.72	60.40	32.46	
0.03501	0.957	13.27	515.78	33.49	4.45	2433.29	58.72	33.49	
0.03601	0.957	13.86	521.25	34.89	4.57	2437.18	57.14	34.89	
0.03701	0.957	14.52	527.11	35.64	4.69	2441.41	55.67	35.64	
0.03801	0.957	15.26	533.56	37.52	4.82	2445.96	54.27	37.52	
0.03901	0.957	16.12	540.66	39.61	4.94	2450.98	52.94	39.61	
0.02301	1.003	9.74	478.46	30.98	3.02	2440.43	99.27	30.98	150.02
0.02401	1.003	9.95	480.94	30.80	3.18	2442.21	94.38	30.80	
0.02501	1.003	10.18	483.70	31.32	3.33	2444.17	89.98	31.32	
0.02601	1.003	10.45	486.78	32.10	3.49	2446.35	85.98	32.10	
0.02701	1.003	10.75	490.15	32.26	3.64	2448.78	82.42	32.26	
0.02801	1.003	11.10	493.97	33.99	3.79	2451.45	79.07	33.99	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.02901	1.003	11.49	498.15	34.47	3.94	2454.45	76.05	34.47	
0.03001	1.003	11.94	502.85	36.08	4.10	2457.76	73.24	36.08	
0.03101	1.003	12.46	508.12	37.91	4.25	2461.47	70.61	37.91	
0.03201	1.003	13.06	513.95	39.38	4.40	2465.61	68.18	39.38	
0.03301	1.003	13.75	520.38	40.81	4.55	2470.19	65.94	40.81	
0.03401	1.003	14.51	527.15	40.72	4.69	2475.17	63.96	40.72	
0.03501	1.003	15.37	534.50	41.96	4.83	2480.46	62.14	41.96	
0.03601	1.003	16.32	542.25	42.25	4.96	2486.15	60.51	42.25	
DATA SET – IV									
0.03901	0.806	8.60	481.95	22.89	3.43	2211.05	51.59	22.89	88.58
0.04001	0.806	8.75	484.03	23.56	3.53	2212.52	50.13	23.56	
0.04101	0.806	8.91	486.27	24.04	3.63	2214.12	48.76	24.04	
0.04201	0.806	9.08	488.54	23.17	3.73	2215.83	47.52	23.17	
0.04301	0.806	9.26	491.01	24.08	3.82	2217.58	46.33	24.08	
0.04401	0.806	9.47	493.65	24.59	3.92	2219.47	45.20	24.59	
0.04501	0.806	9.68	496.44	24.88	4.01	2221.50	44.13	24.88	
0.04601	0.806	9.92	499.40	25.20	4.11	2223.65	43.12	25.20	
0.04701	0.806	10.16	502.42	24.67	4.20	2225.92	42.20	24.67	
0.04801	0.806	10.42	505.56	24.76	4.29	2228.24	41.34	24.76	
0.04901	0.806	10.69	508.90	25.37	4.37	2230.66	40.51	25.37	
0.05001	0.806	10.99	512.38	25.47	4.46	2233.24	39.74	25.47	
0.05101	0.806	11.31	515.99	25.56	4.54	2235.91	39.01	25.56	
0.05201	0.806	11.64	519.75	25.74	4.62	2238.69	38.32	25.74	
0.05301	0.806	12.01	523.78	26.78	4.71	2241.60	37.65	26.78	
0.05401	0.806	12.40	527.88	26.46	4.79	2244.70	37.02	26.46	
0.05501	0.806	12.80	532.12	26.53	4.86	2247.87	36.44	26.53	
0.05601	0.806	13.24	536.50	26.73	4.94	2251.14	35.89	26.73	
0.03001	0.857	8.17	476.59	26.12	3.07	2282.19	70.50	26.12	108.30
0.03101	0.857	8.31	478.61	26.75	3.20	2283.59	67.75	26.75	
0.03201	0.857	8.45	480.72	26.11	3.32	2285.13	65.31	26.11	
0.03301	0.857	8.62	483.06	26.89	3.44	2286.76	63.02	26.89	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.03401	0.857	8.80	485.61	27.59	3.56	2288.55	60.88	27.59	
0.03501	0.857	9.00	488.25	26.81	3.67	2290.50	58.98	26.81	
0.03601	0.857	9.21	491.09	27.17	3.79	2292.52	57.21	27.17	
0.03701	0.857	9.44	494.13	27.61	3.90	2294.69	55.57	27.61	
0.03801	0.857	9.70	497.48	28.73	4.01	2297.03	53.99	28.73	
0.03901	0.857	9.98	501.01	28.89	4.12	2299.59	52.53	28.89	
0.04001	0.857	10.27	504.58	27.83	4.23	2302.28	51.24	27.83	
0.04101	0.857	10.60	508.49	29.12	4.33	2305.02	50.00	29.12	
0.04201	0.857	10.95	512.57	29.13	4.43	2308.01	48.85	29.13	
0.04301	0.857	11.32	516.86	29.35	4.53	2311.14	47.77	29.35	
0.04401	0.857	11.73	521.39	29.90	4.63	2314.42	46.76	29.90	
0.04501	0.857	12.18	526.17	30.37	4.73	2317.90	45.82	30.37	
0.04601	0.857	12.64	531.02	29.82	4.82	2321.55	44.95	29.82	
0.04701	0.857	13.14	536.13	30.38	4.91	2325.28	44.14	30.38	
0.02601	0.905	8.11	476.30	29.56	3.01	2344.96	81.69	29.56	123.04
0.02701	0.905	8.26	478.54	29.56	3.16	2346.54	77.97	29.56	
0.02801	0.905	8.43	480.97	29.48	3.30	2348.26	74.65	29.48	
0.02901	0.905	8.62	483.61	29.59	3.43	2350.13	71.67	29.59	
0.03001	0.905	8.83	486.49	30.01	3.57	2352.16	68.95	30.01	
0.03101	0.905	9.05	489.52	29.51	3.70	2354.36	66.53	29.51	
0.03201	0.905	9.31	492.92	30.92	3.83	2356.71	64.24	30.92	
0.03301	0.905	9.60	496.60	31.45	3.96	2359.31	62.12	31.45	
0.03401	0.905	9.91	500.49	31.35	4.09	2362.13	60.21	31.35	
0.03501	0.905	10.24	504.57	31.14	4.21	2365.10	58.48	31.14	
0.03601	0.905	10.61	508.97	31.94	4.33	2368.24	56.87	31.94	
0.03701	0.905	11.01	513.70	32.61	4.44	2371.62	55.37	32.61	
0.03801	0.905	11.45	518.57	32.13	4.56	2375.22	54.01	32.13	
0.03901	0.905	11.93	523.86	33.42	4.67	2378.97	52.73	33.42	
0.04001	0.905	12.45	529.35	33.32	4.77	2383.01	51.55	33.32	
0.04101	0.905	13.01	535.08	33.52	4.88	2387.21	50.47	33.52	
0.04201	0.905	13.63	541.13	34.07	4.98	2391.61	49.46	34.07	

Time [sec]	Phi	Pressure [bar]	Temperature [K]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	(dr/dt)
0.02401	0.955	8.19	477.99	30.86	3.08	2400.46	88.02	30.86	135.66
0.02501	0.955	8.37	480.64	32.33	3.24	2402.27	83.67	32.33	
0.02601	0.955	8.57	483.45	31.42	3.39	2404.31	79.95	31.42	
0.02701	0.955	8.80	486.61	32.45	3.55	2406.51	76.52	32.45	
0.02801	0.955	9.05	490.01	32.35	3.69	2408.95	73.48	32.35	
0.02901	0.955	9.34	493.71	32.78	3.84	2411.59	70.72	32.78	
0.03001	0.955	9.65	497.76	33.51	3.98	2414.47	68.19	33.51	
0.03101	0.955	10.00	502.11	33.68	4.12	2417.60	65.91	33.68	
0.03201	0.955	10.38	506.74	33.84	4.25	2420.95	63.84	33.84	
0.03301	0.955	10.81	511.72	34.44	4.38	2424.53	61.95	34.44	
0.03401	0.955	11.28	517.02	34.84	4.51	2428.37	60.21	34.84	
0.03501	0.955	11.80	522.75	35.77	4.63	2432.48	58.60	35.77	
0.03601	0.955	12.38	528.87	36.56	4.75	2436.89	57.11	36.56	
0.03701	0.955	13.02	535.35	37.07	4.87	2441.61	55.74	37.07	
0.03801	0.955	13.74	542.39	38.64	4.98	2446.63	54.44	38.64	
0.02301	1.01	8.27	480.33	33.38	3.16	2440.18	97.02	33.38	153.16
0.02401	1.01	8.48	483.23	33.20	3.32	2442.27	92.18	33.20	
0.02501	1.01	8.71	486.43	33.31	3.48	2444.55	87.91	33.31	
0.02601	1.01	8.98	489.97	33.95	3.64	2447.08	84.07	33.95	
0.02701	1.01	9.27	493.81	34.00	3.80	2449.85	80.65	34.00	
0.02801	1.01	9.61	498.15	35.70	3.95	2452.90	77.47	35.70	
0.02901	1.01	9.99	502.89	36.24	4.11	2456.31	74.60	36.24	
0.03001	1.01	10.41	507.99	36.60	4.25	2460.01	72.02	36.60	
0.03101	1.01	10.91	513.80	39.13	4.40	2464.06	69.56	39.13	
0.03201	1.01	11.49	520.22	40.74	4.55	2468.62	67.28	40.74	
0.03301	1.01	12.17	527.52	43.73	4.70	2473.71	65.12	43.73	
0.03401	1.01	12.93	535.23	43.78	4.85	2479.36	63.21	43.78	

Appendix B-2 - R8 Flame Speed Data

DATA SET – I									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Flame Stretch [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.04501	0.694	4.76	485.30	23.72	3.23	1977.08	55.34	23.72	89.40
0.04601	0.694	4.82	487.04	25.21	3.33	1978.29	53.73	25.21	
0.04701	0.694	4.90	488.98	26.67	3.43	1979.66	52.15	26.67	
0.04801	0.694	4.98	490.89	24.84	3.52	1981.18	50.78	24.84	
0.04901	0.694	5.06	492.92	25.15	3.61	1982.69	49.49	25.15	
0.05001	0.694	5.15	495.09	25.82	3.71	1984.29	48.24	25.82	
0.05101	0.694	5.25	497.46	26.74	3.80	1986.01	47.04	26.74	
0.05201	0.694	5.35	499.94	26.96	3.89	1987.87	45.91	26.96	
0.05301	0.694	5.46	502.52	26.59	3.98	1989.83	44.88	26.59	
0.05401	0.694	5.58	505.36	28.14	4.08	1991.87	43.85	28.14	
0.05501	0.694	5.71	508.15	26.59	4.16	1994.10	42.94	26.59	
0.05601	0.694	5.84	511.06	26.65	4.25	1996.31	42.08	26.65	
0.05701	0.694	5.98	514.24	28.13	4.34	1998.61	41.24	28.13	
0.05801	0.694	6.14	517.53	28.03	4.42	2001.13	40.45	28.03	
0.05901	0.694	6.30	520.99	28.49	4.50	2003.73	39.69	28.49	
0.06001	0.694	6.48	524.60	28.77	4.59	2006.47	38.98	28.77	
0.06101	0.694	6.67	528.45	29.79	4.67	2009.34	38.29	29.79	
0.06201	0.694	6.87	532.32	28.94	4.75	2012.39	37.65	28.94	
0.02601	0.795	4.73	483.10	33.25	3.06	2134.57	86.97	33.25	133.00
0.02701	0.795	4.83	485.56	35.33	3.21	2136.21	82.83	35.33	
0.02801	0.795	4.93	488.11	33.61	3.35	2138.11	79.33	33.61	
0.02901	0.795	5.05	491.07	35.94	3.50	2140.09	75.98	35.94	
0.03001	0.795	5.18	494.26	35.86	3.64	2142.37	72.99	35.86	
0.03101	0.795	5.33	497.71	36.19	3.78	2144.84	70.28	36.19	
0.03201	0.795	5.49	501.44	36.48	3.92	2147.51	67.82	36.48	
0.03301	0.795	5.67	505.50	37.30	4.06	2150.40	65.55	37.30	
0.03401	0.795	5.87	509.87	37.84	4.19	2153.54	63.47	37.84	
0.03501	0.795	6.08	514.41	37.24	4.32	2156.92	61.62	37.24	
0.03601	0.795	6.33	519.43	39.02	4.44	2160.45	59.85	39.02	
0.03701	0.795	6.59	524.81	39.74	4.57	2164.34	58.22	39.74	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Flame Stretch [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03801	0.795	6.89	530.50	40.17	4.69	2168.51	56.73	40.17	
0.03901	0.795	7.20	536.42	40.05	4.80	2172.92	55.37	40.05	
0.04001	0.795	7.55	542.70	40.74	4.92	2177.53	54.11	40.74	
0.02101	0.897	4.88	485.09	43.61	3.17	2270.80	108.09	43.61	171.56
0.02201	0.897	5.03	488.63	43.22	3.37	2273.27	101.77	43.22	
0.02301	0.897	5.18	492.39	41.48	3.55	2275.99	96.55	41.48	
0.02401	0.897	5.38	496.85	44.65	3.74	2278.94	91.67	44.65	
0.02501	0.897	5.59	501.68	44.19	3.92	2282.38	87.48	44.19	
0.02601	0.897	5.84	507.04	45.30	4.10	2286.11	83.73	45.30	
0.02701	0.897	6.11	512.79	45.08	4.26	2290.24	80.46	45.08	
0.02801	0.897	6.44	519.28	47.50	4.43	2294.71	77.43	47.50	
0.02901	0.897	6.80	526.30	48.19	4.59	2299.71	74.73	48.19	
0.03001	0.897	7.19	533.61	47.38	4.74	2305.09	72.38	47.38	
0.03101	0.897	7.65	541.70	49.71	4.89	2310.75	70.21	49.71	
0.01801	0.999	4.75	483.91	43.62	3.07	2540.09	130.75	43.62	200.40
0.01901	0.999	4.91	487.65	43.94	3.29	2540.18	121.91	43.94	
0.02001	0.999	5.09	492.00	45.51	3.51	2540.28	114.27	45.51	
0.02101	0.999	5.31	497.07	47.49	3.73	2540.41	107.57	47.49	
0.02201	0.999	5.55	502.61	47.37	3.93	2540.55	101.95	47.37	
0.02301	0.999	5.85	508.92	49.49	4.13	2540.71	96.95	49.49	
0.02401	0.999	6.18	515.82	50.22	4.33	2540.89	92.64	50.22	
0.02501	0.999	6.57	523.47	52.07	4.51	2541.08	88.81	52.07	
0.02601	0.999	7.02	531.96	54.46	4.69	2541.30	85.38	54.46	
0.02701	0.999	7.53	541.03	55.14	4.86	2541.54	82.40	55.14	
DATA SET – II									
0.04601	0.693	8.22	483.74	21.24	3.11	1975.59	46.89	21.24	72.89
0.04701	0.693	8.31	485.05	20.67	3.19	1976.60	45.70	20.67	
0.04801	0.693	8.40	486.43	20.94	3.27	1977.63	44.57	20.94	
0.04901	0.693	8.50	487.92	21.42	3.35	1978.72	43.48	21.42	
0.05001	0.693	8.60	489.32	19.29	3.43	1979.89	42.56	19.29	
0.05101	0.693	8.71	490.94	21.38	3.50	1981.00	41.60	21.38	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Flame Stretch [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.05201	0.693	8.84	492.70	22.25	3.59	1982.28	40.65	22.25	
0.05301	0.693	8.96	494.44	21.12	3.66	1983.67	39.80	21.12	
0.05401	0.693	9.09	496.24	21.14	3.74	1985.04	39.00	21.14	
0.05501	0.693	9.23	498.19	21.91	3.81	1986.47	38.22	21.91	
0.05601	0.693	9.38	500.21	21.80	3.89	1988.01	37.48	21.80	
0.05701	0.693	9.54	502.35	22.38	3.97	1989.61	36.76	22.38	
0.05801	0.693	9.71	504.60	22.70	4.04	1991.30	36.07	22.70	
0.05901	0.693	9.89	506.97	23.05	4.12	1993.09	35.41	23.05	
0.06001	0.693	10.08	509.37	22.59	4.19	1994.96	34.79	22.59	
0.06101	0.693	10.27	511.78	21.99	4.26	1996.86	34.23	21.99	
0.06201	0.693	10.48	514.36	22.87	4.33	1998.77	33.67	22.87	
0.06301	0.693	10.70	517.04	23.10	4.40	2000.82	33.13	23.10	
0.06401	0.693	10.92	519.80	23.02	4.47	2002.95	32.63	23.02	
0.06501	0.693	11.17	522.68	23.45	4.54	2005.13	32.13	23.45	
0.06601	0.693	11.42	525.66	23.58	4.60	2007.42	31.67	23.58	
0.06701	0.693	11.69	528.71	23.58	4.67	2009.79	31.22	23.58	
0.06801	0.693	11.97	531.90	24.01	4.73	2012.22	30.79	24.01	
0.06901	0.693	12.28	535.24	24.50	4.80	2014.76	30.37	24.50	
0.07001	0.693	12.59	538.60	24.13	4.86	2017.42	29.98	24.13	
0.07101	0.693	12.91	542.06	24.33	4.92	2020.10	29.61	24.33	
0.02801	0.8	8.02	483.41	29.84	3.03	2145.88	74.93	29.84	113.33
0.02901	0.8	8.15	485.37	29.00	3.15	2147.32	71.93	29.00	
0.03001	0.8	8.30	487.59	30.39	3.28	2148.85	69.09	30.39	
0.03101	0.8	8.46	489.93	29.71	3.40	2150.57	66.58	29.71	
0.03201	0.8	8.64	492.41	29.57	3.52	2152.37	64.30	29.57	
0.03301	0.8	8.83	495.20	31.17	3.65	2154.31	62.11	31.17	
0.03401	0.8	9.05	498.14	30.81	3.77	2156.47	60.14	30.81	
0.03501	0.8	9.28	501.30	31.24	3.89	2158.75	58.31	31.24	
0.03601	0.8	9.53	504.71	31.91	4.00	2161.20	56.60	31.91	
0.03701	0.8	9.82	508.38	32.46	4.12	2163.85	55.00	32.46	
0.03801	0.8	10.11	512.15	31.82	4.23	2166.69	53.57	31.82	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Flame Stretch [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03901	0.8	10.44	516.21	32.74	4.34	2169.62	52.21	32.74	
0.04001	0.8	10.79	520.47	32.78	4.45	2172.78	50.96	32.78	
0.04101	0.8	11.17	524.96	33.17	4.55	2176.09	49.79	33.17	
0.04201	0.8	11.58	529.63	33.11	4.65	2179.58	48.71	33.11	
0.04301	0.8	12.03	534.66	34.36	4.75	2183.22	47.68	34.36	
0.04401	0.8	12.51	539.85	34.25	4.85	2187.14	46.74	34.25	
0.04501	0.8	13.02	545.22	34.23	4.94	2191.19	45.86	34.23	
0.02201	0.908	8.09	484.47	36.07	3.04	2291.81	98.05	36.07	149.04
0.02301	0.908	8.28	487.26	36.83	3.21	2293.72	92.79	36.83	
0.02401	0.908	8.49	490.37	37.38	3.38	2295.88	88.12	37.38	
0.02501	0.908	8.73	493.77	37.28	3.55	2298.30	84.04	37.28	
0.02601	0.908	9.00	497.51	37.61	3.71	2300.93	80.41	37.61	
0.02701	0.908	9.31	501.60	38.07	3.86	2303.83	77.15	38.07	
0.02801	0.908	9.66	506.14	39.29	4.02	2307.01	74.16	39.29	
0.02901	0.908	10.04	511.05	39.73	4.17	2310.52	71.47	39.73	
0.03001	0.908	10.47	516.25	39.40	4.31	2314.31	69.09	39.40	
0.03101	0.908	10.94	521.89	40.43	4.46	2318.33	66.91	40.43	
0.03201	0.908	11.47	527.92	40.87	4.59	2322.69	64.93	40.87	
0.03301	0.908	12.07	534.50	42.34	4.73	2327.37	63.08	42.34	
0.03401	0.908	12.72	541.36	42.16	4.85	2332.43	61.44	42.16	
0.03501	0.908	13.44	548.65	42.88	4.97	2337.74	59.93	42.88	
0.02001	1.014	8.31	487.63	40.94	3.19	2380.93	119.26	40.94	190.04
0.02101	1.014	8.55	491.13	40.38	3.38	2383.44	112.43	40.38	
0.02201	1.014	8.85	495.21	42.20	3.58	2386.27	106.29	42.20	
0.02301	1.014	9.18	499.68	41.96	3.76	2389.49	101.03	41.96	
0.02401	1.014	9.60	505.12	46.52	3.96	2393.13	95.98	46.52	
0.02501	1.014	10.10	511.30	48.37	4.16	2397.47	91.47	48.37	
0.02601	1.014	10.68	518.30	50.43	4.35	2402.39	87.42	50.43	
0.02701	1.014	11.36	526.10	52.10	4.53	2407.93	83.82	52.10	
0.02801	1.014	12.16	534.79	54.15	4.72	2414.10	80.60	54.15	
0.02901	1.014	13.06	543.96	53.69	4.88	2420.86	77.84	53.69	

DATA SET – III									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Flame Stretch [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.04001	0.713	6.57	483.30	22.67	3.08	2008.05	55.69	22.67	85.64
0.04101	0.713	6.65	484.86	24.53	3.17	2009.12	53.96	24.53	
0.04201	0.713	6.75	486.57	25.28	3.27	2010.35	52.32	25.28	
0.04301	0.713	6.84	488.30	24.32	3.37	2011.69	50.85	24.32	
0.04401	0.713	6.95	490.17	24.80	3.46	2013.05	49.46	24.80	
0.04501	0.713	7.05	492.09	24.20	3.55	2014.52	48.19	24.20	
0.04601	0.713	7.17	494.08	24.03	3.64	2016.02	47.01	24.03	
0.04701	0.713	7.30	496.32	25.71	3.74	2017.60	45.84	25.71	
0.04801	0.713	7.43	498.63	25.34	3.83	2019.36	44.75	25.34	
0.04901	0.713	7.57	501.03	25.21	3.92	2021.17	43.74	25.21	
0.05001	0.713	7.73	503.54	25.30	4.00	2023.06	42.80	25.30	
0.05101	0.713	7.89	506.23	25.99	4.09	2025.04	41.88	25.99	
0.05201	0.713	8.07	509.04	26.22	4.18	2027.15	41.02	26.22	
0.05301	0.713	8.26	512.01	26.64	4.26	2029.37	40.19	26.64	
0.05401	0.713	8.45	515.07	26.48	4.34	2031.71	39.42	26.48	
0.05501	0.713	8.66	518.23	26.42	4.43	2034.13	38.70	26.42	
0.05601	0.713	8.89	521.54	26.77	4.51	2036.62	38.02	26.77	
0.05701	0.713	9.12	525.02	27.24	4.58	2039.24	37.36	27.24	
0.05801	0.713	9.37	528.56	26.99	4.66	2041.98	36.74	26.99	
0.05901	0.713	9.64	532.31	27.66	4.74	2044.79	36.15	27.66	
0.06001	0.713	9.92	536.15	27.64	4.81	2047.75	35.59	27.64	
0.06101	0.713	10.22	540.14	27.86	4.88	2050.80	35.06	27.86	
0.06201	0.713	10.55	544.35	28.70	4.96	2053.96	34.55	28.70	
0.02801	0.808	6.66	485.42	32.55	3.20	2157.64	76.49	32.55	122.22
0.02901	0.808	6.79	487.86	32.17	3.33	2159.39	73.35	32.17	
0.03001	0.808	6.95	490.61	33.53	3.47	2161.29	70.40	33.53	
0.03101	0.808	7.10	493.39	31.59	3.60	2163.40	67.89	31.59	
0.03201	0.808	7.29	496.57	33.74	3.73	2165.56	65.47	33.74	
0.03301	0.808	7.50	500.02	34.36	3.87	2168.02	63.23	34.36	
0.03401	0.808	7.71	503.59	33.35	3.99	2170.69	61.26	33.35	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Flame Stretch [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03501	0.808	7.95	507.43	34.05	4.11	2173.45	59.43	34.05	
0.03601	0.808	8.22	511.66	35.42	4.24	2176.44	57.69	35.42	
0.03701	0.808	8.51	516.10	35.31	4.36	2179.71	56.11	35.31	
0.03801	0.808	8.83	520.76	35.37	4.47	2183.15	54.67	35.37	
0.03901	0.808	9.17	525.75	36.17	4.58	2186.76	53.32	36.17	
0.04001	0.808	9.54	530.92	35.97	4.69	2190.63	52.09	35.97	
0.04101	0.808	9.95	536.39	36.57	4.80	2194.65	50.94	36.57	
0.04201	0.808	10.39	542.18	37.26	4.90	2198.90	49.86	37.26	
0.02201	0.897	6.57	484.60	36.00	3.13	2275.67	99.49	36.00	155.77
0.02301	0.897	6.74	487.72	39.32	3.31	2277.70	94.07	39.32	
0.02401	0.897	6.94	491.15	39.16	3.49	2280.12	89.37	39.16	
0.02501	0.897	7.15	494.85	38.59	3.65	2282.77	85.32	38.59	
0.02601	0.897	7.40	499.00	39.82	3.82	2285.64	81.63	39.82	
0.02701	0.897	7.67	503.46	39.74	3.98	2288.84	78.37	39.74	
0.02801	0.897	7.98	508.46	41.36	4.13	2292.31	75.37	41.36	
0.02901	0.897	8.33	513.83	41.55	4.29	2296.16	72.69	41.55	
0.03001	0.897	8.72	519.63	42.25	4.43	2300.31	70.27	42.25	
0.03101	0.897	9.15	525.82	42.53	4.58	2304.78	68.09	42.53	
0.03201	0.897	9.64	532.48	43.43	4.71	2309.56	66.10	43.43	
0.03301	0.897	10.17	539.49	43.55	4.84	2314.69	64.32	43.55	
0.01901	0.995	6.51	484.05	34.47	3.02	2565.40	123.82	34.47	187.14
0.02001	0.995	6.70	487.47	43.22	3.24	2366.43	115.69	43.22	
0.02101	0.995	6.92	491.44	44.41	3.45	2369.17	108.63	44.41	
0.02201	0.995	7.18	495.74	43.24	3.64	2372.29	102.77	43.24	
0.02301	0.995	7.47	500.68	45.12	3.84	2375.72	97.52	45.12	
0.02401	0.995	7.81	506.03	44.74	4.02	2379.60	93.03	44.74	
0.02501	0.995	8.20	512.11	46.86	4.21	2383.85	88.95	46.86	
0.02601	0.995	8.65	518.83	47.93	4.39	2388.64	85.32	47.93	
0.02701	0.995	9.18	526.22	49.17	4.56	2393.92	82.09	49.17	
0.02801	0.995	9.80	534.59	52.23	4.73	2399.77	79.10	52.23	
0.02901	0.995	10.54	544.06	55.61	4.90	2406.40	76.34	55.61	

DATA SET – IV									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Flame Stretch [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.03634	0.72	9.93	482.66	24.07	3.05	2020.13	56.76	24.07	86.70
0.03734	0.72	10.06	484.18	24.07	3.15	2021.25	55.01	24.07	
0.03834	0.72	10.19	485.80	24.03	3.25	2022.45	53.38	24.03	
0.03934	0.72	10.34	487.59	25.31	3.35	2023.71	51.80	25.31	
0.04034	0.72	10.50	489.46	24.84	3.44	2025.13	50.35	24.84	
0.04134	0.72	10.66	491.34	23.81	3.53	2026.59	49.06	23.81	
0.04234	0.72	10.84	493.42	25.07	3.63	2028.07	47.79	25.07	
0.04334	0.72	11.03	495.65	25.66	3.72	2029.71	46.58	25.66	
0.04434	0.72	11.24	498.00	25.71	3.81	2031.46	45.45	25.71	
0.04534	0.72	11.46	500.43	25.44	3.90	2033.31	44.41	25.44	
0.04634	0.72	11.70	503.00	25.91	3.99	2035.22	43.41	25.91	
0.04734	0.72	11.94	505.64	25.41	4.08	2037.25	42.49	25.41	
0.04834	0.72	12.21	508.50	26.51	4.17	2039.33	41.60	26.51	
0.04934	0.72	12.50	511.43	26.19	4.25	2041.58	40.77	26.19	
0.05034	0.72	12.80	514.49	26.42	4.34	2043.90	39.98	26.42	
0.05134	0.72	13.11	517.66	26.33	4.42	2046.32	39.24	26.33	
0.05234	0.72	13.46	521.03	27.14	4.50	2048.82	38.53	27.14	
0.05334	0.72	13.83	524.57	27.60	4.58	2051.48	37.85	27.60	
0.05434	0.72	14.21	528.16	27.12	4.66	2054.28	37.22	27.12	
0.05534	0.72	14.61	531.88	27.32	4.73	2057.12	36.62	27.32	
0.05634	0.72	15.04	535.75	27.68	4.81	2060.07	36.05	27.68	
0.05734	0.72	15.50	539.76	27.86	4.88	2063.14	35.51	27.86	
0.05834	0.72	16.00	544.03	28.88	4.96	2066.32	34.98	28.88	
0.02801	0.833	9.93	483.79	28.86	3.08	2195.98	74.18	28.86	114.09
0.02901	0.833	10.10	485.84	28.52	3.20	2197.46	71.26	28.52	
0.03001	0.833	10.29	488.18	30.19	3.33	2199.05	68.46	30.19	
0.03101	0.833	10.51	490.72	30.56	3.46	2200.86	65.90	30.56	
0.03201	0.833	10.73	493.27	28.66	3.58	2202.81	63.72	28.66	
0.03301	0.833	10.99	496.15	30.38	3.70	2204.79	61.61	30.38	
0.03401	0.833	11.27	499.30	31.28	3.83	2207.02	59.63	31.28	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Flame Stretch [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03501	0.833	11.57	502.61	30.95	3.95	2209.46	57.84	30.95	
0.03601	0.833	11.90	506.12	31.14	4.06	2212.01	56.19	31.14	
0.03701	0.833	12.26	509.80	31.02	4.17	2214.73	54.68	31.02	
0.03801	0.833	12.64	513.74	31.71	4.28	2217.58	53.26	31.71	
0.03901	0.833	13.07	517.95	32.27	4.39	2220.64	51.94	32.27	
0.04001	0.833	13.52	522.34	32.21	4.50	2223.89	50.72	32.21	
0.04101	0.833	14.02	526.99	32.82	4.60	2227.30	49.58	32.82	
0.04201	0.833	14.55	531.85	32.97	4.70	2230.91	48.52	32.97	
0.04301	0.833	15.12	536.94	33.24	4.80	2234.68	47.54	33.24	
0.04401	0.833	15.75	542.33	34.05	4.90	2238.63	46.60	34.05	
0.02401	0.907	10.09	486.16	33.63	3.18	2295.08	88.12	33.63	140.19
0.02501	0.907	10.33	488.98	34.60	3.34	2297.03	83.95	34.60	
0.02601	0.907	10.59	492.04	34.48	3.49	2299.22	80.27	34.48	
0.02701	0.907	10.89	495.41	34.94	3.64	2301.59	76.95	34.94	
0.02801	0.907	11.23	499.16	36.05	3.79	2304.21	73.90	36.05	
0.02901	0.907	11.60	503.17	35.96	3.94	2307.11	71.17	35.96	
0.03001	0.907	12.01	507.53	36.53	4.08	2310.22	68.69	36.53	
0.03101	0.907	12.47	512.19	36.76	4.22	2313.58	66.45	36.76	
0.03201	0.907	12.98	517.22	37.50	4.35	2317.19	64.39	37.50	
0.03301	0.907	13.54	522.68	38.46	4.49	2321.10	62.49	38.46	
0.03401	0.907	14.17	528.48	38.90	4.62	2325.31	60.75	38.90	
0.03501	0.907	14.87	534.67	39.53	4.74	2329.81	59.16	39.53	
0.03601	0.907	15.67	541.54	41.96	4.86	2334.63	57.63	41.96	
0.02101	0.986	10.03	485.78	37.08	3.11	2370.54	112.46	37.08	174.92
0.02201	0.986	10.30	488.89	37.90	3.29	2372.72	106.22	37.90	
0.02301	0.986	10.59	492.28	37.27	3.47	2375.17	100.90	37.27	
0.02401	0.986	10.94	496.18	39.16	3.64	2377.87	96.01	39.16	
0.02501	0.986	11.36	500.70	41.30	3.82	2380.99	91.51	41.30	
0.02601	0.986	11.84	505.76	42.65	4.00	2384.56	87.45	42.65	
0.02701	0.986	12.40	511.56	44.99	4.18	2388.60	83.72	44.99	
0.02801	0.986	13.07	518.07	46.91	4.36	2393.18	80.32	46.91	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Flame Stretch [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02901	0.986	13.84	525.32	48.67	4.53	2398.31	77.25	48.67	
0.03001	0.986	14.71	533.09	49.00	4.69	2403.97	74.56	49.00	
0.03101	0.986	15.68	541.41	49.46	4.85	2410.04	72.17	49.46	

Appendix B-3 - R8 – JP-8 Flame Speed Data

DATA SET – I									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Flame Stretch [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.03601	0.654	4.75	483.66	30.66	3.14	1925.75	66.42	30.66	104.36
0.03701	0.654	4.82	485.52	29.25	3.25	1927.19	64.15	29.25	
0.03801	0.654	4.90	487.52	29.44	3.36	1928.67	62.04	29.44	
0.03901	0.654	4.99	489.67	29.80	3.47	1930.25	60.09	29.80	
0.04001	0.654	5.08	492.02	30.59	3.58	1931.95	58.24	30.59	
0.04101	0.654	5.19	494.62	32.04	3.70	1933.82	56.45	32.04	
0.04201	0.654	5.30	497.37	32.07	3.81	1935.88	54.81	32.07	
0.04301	0.654	5.42	500.25	31.85	3.92	1938.07	53.30	31.85	
0.04401	0.654	5.55	503.20	30.99	4.02	1940.36	51.95	30.99	
0.04501	0.654	5.69	506.41	32.16	4.12	1942.70	50.64	32.16	
0.04601	0.654	5.85	509.89	33.35	4.23	1945.26	49.39	33.35	
0.04701	0.654	6.01	513.49	32.94	4.33	1948.02	48.25	32.94	
0.04801	0.654	6.19	517.22	32.85	4.42	1950.88	47.19	32.85	
0.04901	0.654	6.38	521.33	34.72	4.52	1953.87	46.15	34.72	
0.05001	0.654	6.59	525.55	34.27	4.62	1957.14	45.19	34.27	
0.05101	0.654	6.82	530.02	35.12	4.71	1960.51	44.28	35.12	
0.05201	0.654	7.06	534.68	35.33	4.81	1964.08	43.43	35.33	
0.02301	0.758	4.74	483.03	39.61	3.09	2098.54	100.10	39.61	154.51
0.02401	0.758	4.85	485.91	40.97	3.26	2100.49	94.76	40.97	
0.02501	0.758	4.97	489.00	39.91	3.43	2102.73	90.22	39.91	
0.02601	0.758	5.12	492.61	42.48	3.59	2105.13	85.96	42.48	
0.02701	0.758	5.28	496.56	42.79	3.76	2107.93	82.18	42.79	
0.02801	0.758	5.47	500.97	43.96	3.92	2111.01	78.75	43.96	
0.02901	0.758	5.68	505.64	43.40	4.08	2114.43	75.76	43.40	
0.03001	0.758	5.92	510.92	45.78	4.24	2118.07	72.94	45.78	
0.03101	0.758	6.18	516.43	44.77	4.38	2122.17	70.50	44.77	
0.03201	0.758	6.47	522.41	45.94	4.53	2126.46	68.25	45.94	
0.03301	0.758	6.80	528.94	47.42	4.67	2131.13	66.18	47.42	
0.03401	0.758	7.16	535.76	47.13	4.80	2136.22	64.34	47.13	
0.03501	0.758	7.57	543.15	48.71	4.93	2141.55	62.63	48.71	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Flame Stretch [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.01901	0.834	4.89	485.85	49.32	3.25	2213.20	123.50	49.32	200.56
0.02001	0.834	5.06	490.07	50.32	3.47	2216.03	115.64	50.32	
0.02101	0.834	5.27	495.10	53.23	3.69	2219.31	108.64	53.23	
0.02201	0.834	5.52	500.71	53.42	3.91	2223.19	102.70	53.42	
0.02301	0.834	5.80	506.96	54.09	4.11	2227.52	97.58	54.09	
0.02401	0.834	6.12	513.64	53.23	4.30	2232.31	93.26	53.23	
0.02501	0.834	6.50	521.42	57.36	4.49	2237.50	89.25	57.36	
0.02601	0.834	6.94	529.93	58.34	4.68	2243.51	85.74	58.34	
0.02701	0.834	7.43	538.96	58.15	4.85	2250.05	82.72	58.15	
0.01601	0.951	4.81	483.99	53.47	3.11	2347.96	149.81	53.47	232.98
0.01701	0.951	4.99	488.51	53.30	3.37	2351.04	138.35	53.30	
0.01801	0.951	5.22	493.96	55.89	3.62	2354.66	128.55	55.89	
0.01901	0.951	5.51	500.36	57.94	3.88	2358.98	120.21	57.94	
0.02001	0.951	5.84	507.66	59.04	4.12	2364.01	113.20	59.04	
0.02101	0.951	6.23	515.77	59.54	4.34	2369.69	107.31	59.54	
0.02201	0.951	6.71	525.14	62.97	4.56	2376.08	102.09	62.97	
0.02301	0.951	7.26	535.28	63.01	4.77	2383.32	97.71	63.01	
0.02401	0.951	7.93	546.81	66.80	4.97	2391.26	93.79	66.80	

DATA SET – II									
Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.06601	0.657	7.17	496.01	20.43	3.72	1941.31	36.36	20.43	67.70
0.06701	0.657	7.28	497.85	21.01	3.80	1942.70	35.67	21.01	
0.06801	0.657	7.39	499.80	21.52	3.87	1944.16	35.01	21.52	
0.06901	0.657	7.51	501.84	21.70	3.94	1945.72	34.37	21.70	
0.07001	0.657	7.64	503.90	21.18	4.01	1947.33	33.78	21.18	
0.07101	0.657	7.77	506.10	21.88	4.08	1948.97	33.20	21.88	
0.07201	0.657	7.91	508.37	22.09	4.15	1950.72	32.64	22.09	
0.07301	0.657	8.06	510.70	21.84	4.22	1952.54	32.12	21.84	
0.07401	0.657	8.21	513.07	21.61	4.28	1954.39	31.63	21.61	
0.07501	0.657	8.37	515.59	22.35	4.35	1956.28	31.15	22.35	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.07601	0.657	8.55	518.21	22.78	4.41	1958.29	30.68	22.78	
0.07701	0.657	8.72	520.88	22.35	4.48	1960.38	30.24	22.35	
0.07801	0.657	8.91	523.62	22.52	4.54	1962.51	29.82	22.52	
0.07901	0.657	9.11	526.48	22.85	4.60	1964.70	29.41	22.85	
0.03101	0.762	6.39	482.50	27.82	3.07	2106.46	70.16	27.82	107.82
0.03201	0.762	6.50	484.42	28.16	3.19	2107.82	67.54	28.16	
0.03301	0.762	6.61	486.55	28.97	3.31	2109.31	65.09	28.97	
0.03401	0.762	6.73	488.84	29.31	3.43	2110.96	62.83	29.31	
0.03501	0.762	6.87	491.36	30.08	3.55	2112.75	60.70	30.08	
0.03601	0.762	7.02	493.92	28.86	3.66	2114.70	58.84	28.86	
0.03701	0.762	7.18	496.79	30.42	3.78	2116.69	57.04	30.42	
0.03801	0.762	7.35	499.75	29.74	3.89	2118.92	55.42	29.74	
0.03901	0.762	7.54	502.90	30.07	4.00	2121.22	53.91	30.07	
0.04001	0.762	7.74	506.29	30.69	4.11	2123.67	52.49	30.69	
0.04101	0.762	7.97	509.93	31.56	4.22	2126.30	51.14	31.56	
0.04201	0.762	8.22	513.82	32.09	4.32	2129.15	49.88	32.09	
0.04301	0.762	8.47	517.79	31.45	4.42	2132.17	48.74	31.45	
0.04401	0.762	8.75	522.00	32.02	4.52	2135.26	47.66	32.02	
0.04501	0.762	9.05	526.38	32.02	4.62	2138.55	46.67	32.02	
0.04601	0.762	9.38	531.03	32.81	4.72	2141.97	45.72	32.81	
0.04701	0.762	9.73	535.86	32.87	4.81	2145.60	44.84	32.87	
0.04801	0.762	10.10	540.92	33.35	4.90	2149.38	44.01	33.35	
0.02401	0.852	6.40	483.87	33.79	3.14	2240.32	91.27	33.79	143.48
0.02501	0.852	6.55	486.74	36.82	3.31	2242.19	86.71	36.82	
0.02601	0.852	6.72	489.91	36.90	3.47	2244.40	82.68	36.90	
0.02701	0.852	6.91	493.27	36.21	3.62	2246.83	79.18	36.21	
0.02801	0.852	7.13	497.03	37.32	3.78	2249.43	75.98	37.32	
0.02901	0.852	7.37	501.14	37.94	3.93	2252.32	73.07	37.94	
0.03001	0.852	7.63	505.46	37.33	4.07	2255.48	70.51	37.33	
0.03101	0.852	7.93	510.35	39.57	4.22	2258.82	68.08	39.57	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03201	0.852	8.26	515.56	39.78	4.36	2262.58	65.89	39.78	
0.03301	0.852	8.62	521.03	39.46	4.49	2266.59	63.93	39.46	
0.03401	0.852	9.03	526.89	40.22	4.62	2270.80	62.14	40.22	
0.03501	0.852	9.47	533.12	40.71	4.74	2275.32	60.50	40.71	
0.03601	0.852	9.95	539.71	41.19	4.86	2280.12	59.00	41.19	
0.02001	0.945	6.39	483.17	38.50	3.07	2349.15	111.04	38.50	170.35
0.02101	0.945	6.57	486.42	40.56	3.26	2351.33	104.38	40.56	
0.02201	0.945	6.78	490.17	41.77	3.46	2353.90	98.51	41.77	
0.02301	0.945	7.01	494.22	40.95	3.64	2356.80	93.54	40.95	
0.02401	0.945	7.28	498.83	42.50	3.83	2359.98	89.06	42.50	
0.02501	0.945	7.58	503.77	41.87	4.00	2363.55	85.21	41.87	
0.02601	0.945	7.93	509.39	44.09	4.17	2367.43	81.67	44.09	
0.02701	0.945	8.32	515.46	44.28	4.34	2371.78	78.54	44.28	
0.02801	0.945	8.76	521.93	44.20	4.49	2376.47	75.80	44.20	
0.02901	0.945	9.26	529.04	45.82	4.65	2381.49	73.28	45.82	
0.03001	0.945	9.83	536.69	46.53	4.80	2387.00	71.03	46.53	
0.03101	0.945	10.48	545.13	48.81	4.94	2392.94	68.93	48.81	
DATA SET – III									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Stretch Rate [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.06301	0.654	8.31	485.82	16.93	3.21	1928.79	36.61	16.93	58.84
0.06401	0.654	8.38	486.99	18.01	3.28	1929.64	35.86	18.01	
0.06501	0.654	8.46	488.14	17.02	3.34	1930.56	35.18	17.02	
0.06601	0.654	8.55	489.36	17.54	3.41	1931.48	34.52	17.54	
0.06701	0.654	8.63	490.61	17.22	3.47	1932.45	33.90	17.22	
0.06801	0.654	8.72	491.93	17.50	3.53	1933.44	33.30	17.50	
0.06901	0.654	8.82	493.27	17.29	3.60	1934.49	32.73	17.29	
0.07001	0.654	8.91	494.65	17.31	3.66	1935.55	32.19	17.31	
0.07101	0.654	9.02	496.11	17.68	3.72	1936.65	31.66	17.68	
0.07201	0.654	9.13	497.69	18.51	3.78	1937.81	31.13	18.51	
0.07301	0.654	9.25	499.34	18.70	3.84	1939.07	30.61	18.70	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.07401	0.654	9.38	501.03	18.63	3.91	1940.38	30.13	18.63	
0.07501	0.654	9.50	502.69	17.74	3.96	1941.73	29.68	17.74	
0.07601	0.654	9.63	504.48	18.72	4.03	1943.05	29.24	18.72	
0.07701	0.654	9.77	506.31	18.48	4.08	1944.48	28.81	18.48	
0.07801	0.654	9.92	508.23	18.99	4.14	1945.93	28.39	18.99	
0.07901	0.654	10.07	510.15	18.49	4.20	1947.47	28.01	18.49	
0.08001	0.654	10.23	512.19	19.11	4.26	1949.00	27.62	19.11	
0.08101	0.654	10.39	514.25	18.85	4.32	1950.62	27.26	18.85	
0.08201	0.654	10.56	516.38	19.00	4.37	1952.27	26.90	19.00	
0.08301	0.654	10.74	518.60	19.32	4.43	1953.97	26.56	19.32	
0.08401	0.654	10.93	520.82	18.93	4.48	1955.74	26.24	18.93	
0.08501	0.654	11.13	523.20	19.78	4.54	1957.52	25.92	19.78	
0.08601	0.654	11.33	525.60	19.56	4.59	1959.42	25.61	19.56	
0.08701	0.654	11.54	528.07	19.69	4.65	1961.34	25.31	19.69	
0.08801	0.654	11.77	530.65	20.18	4.70	1963.31	25.02	20.18	
0.08901	0.654	12.00	533.22	19.71	4.75	1965.38	24.75	19.71	
0.09001	0.654	12.24	535.88	20.02	4.81	1967.44	24.48	20.02	
0.09101	0.654	12.49	538.57	19.79	4.86	1969.58	24.23	19.79	
0.03401	0.752	8.17	483.15	26.09	3.08	2092.05	62.05	26.09	95.49
0.03501	0.752	8.28	484.80	24.57	3.18	2093.32	60.05	24.57	
0.03601	0.752	8.42	486.73	27.01	3.29	2094.61	58.02	27.01	
0.03701	0.752	8.55	488.64	25.02	3.39	2096.11	56.29	25.02	
0.03801	0.752	8.70	490.77	26.40	3.50	2097.60	54.60	26.40	
0.03901	0.752	8.86	493.03	26.52	3.60	2099.26	53.03	26.52	
0.04001	0.752	9.02	495.34	25.68	3.70	2101.02	51.62	25.68	
0.04101	0.752	9.21	497.89	26.96	3.80	2102.82	50.25	26.96	
0.04201	0.752	9.41	500.59	27.27	3.90	2104.80	48.96	27.27	
0.04301	0.752	9.63	503.50	27.93	4.00	2106.92	47.74	27.93	
0.04401	0.752	9.86	506.49	27.52	4.10	2109.18	46.62	27.52	
0.04501	0.752	10.11	509.62	27.55	4.19	2111.52	45.57	27.55	
0.04601	0.752	10.36	512.86	27.37	4.28	2113.96	44.60	27.37	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.04701	0.752	10.65	516.36	28.50	4.37	2116.49	43.66	28.50	
0.04801	0.752	10.96	520.02	28.67	4.46	2119.23	42.78	28.67	
0.04901	0.752	11.28	523.79	28.54	4.55	2122.09	41.96	28.54	
0.05001	0.752	11.62	527.68	28.50	4.64	2125.04	41.19	28.50	
0.05101	0.752	11.99	531.87	29.65	4.72	2128.10	40.45	29.65	
0.05201	0.752	12.39	536.13	29.30	4.80	2131.38	39.76	29.30	
0.05301	0.752	12.81	540.62	29.92	4.88	2134.72	39.10	29.92	
0.02501	0.857	8.10	484.53	31.76	3.10	2250.25	85.51	31.76	132.65
0.02601	0.857	8.27	487.07	33.48	3.25	2251.96	81.53	33.48	
0.02701	0.857	8.45	489.79	32.84	3.40	2253.92	78.05	32.84	
0.02801	0.857	8.67	492.84	34.03	3.55	2256.02	74.83	34.03	
0.02901	0.857	8.90	496.07	33.53	3.69	2258.36	71.99	33.53	
0.03001	0.857	9.16	499.61	34.25	3.82	2260.86	69.38	34.25	
0.03101	0.857	9.45	503.51	35.27	3.96	2263.59	66.95	35.27	
0.03201	0.857	9.77	507.68	35.38	4.10	2266.60	64.76	35.38	
0.03301	0.857	10.12	512.09	35.42	4.23	2269.80	62.78	35.42	
0.03401	0.857	10.51	516.85	36.13	4.35	2273.21	60.94	36.13	
0.03501	0.857	10.93	521.86	36.11	4.48	2276.87	59.28	36.11	
0.03601	0.857	11.39	527.17	36.56	4.59	2280.73	57.74	36.56	
0.03701	0.857	11.89	532.85	37.42	4.71	2284.83	56.32	37.42	
0.03801	0.857	12.45	538.86	37.93	4.82	2289.21	55.00	37.93	
0.02101	0.941	8.19	484.39	37.33	3.08	2351.19	105.33	37.33	162.23
0.02201	0.941	8.40	487.52	38.91	3.27	2353.31	99.31	38.91	
0.02301	0.941	8.64	490.84	37.35	3.44	2355.72	94.31	37.35	
0.02401	0.941	8.91	494.65	39.04	3.62	2358.33	89.74	39.04	
0.02501	0.941	9.23	498.84	39.35	3.79	2361.30	85.70	39.35	
0.02601	0.941	9.58	503.43	39.78	3.95	2364.56	82.12	39.78	
0.02701	0.941	9.98	508.52	40.89	4.11	2368.14	78.87	40.89	
0.02801	0.941	10.43	513.99	41.06	4.27	2372.08	75.98	41.06	
0.02901	0.941	10.93	519.99	42.22	4.42	2376.33	73.35	42.22	
0.03001	0.941	11.51	526.47	42.97	4.57	2380.98	70.97	42.97	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03101	0.941	12.19	533.91	46.60	4.72	2386.07	68.68	46.60	
0.03201	0.941	12.98	542.04	48.25	4.87	2391.85	66.60	48.25	
DATA SET – IV									
0.06901	0.63	9.18	483.56	15.52	3.11	1884.59	32.60	15.52	50.69
0.07001	0.63	9.25	484.45	15.19	3.17	1885.29	32.02	15.19	
0.07101	0.63	9.32	485.35	14.76	3.22	1886.01	31.48	14.76	
0.07201	0.63	9.39	486.28	14.90	3.27	1886.72	30.96	14.90	
0.07301	0.63	9.46	487.26	15.02	3.33	1887.47	30.46	15.02	
0.07401	0.63	9.54	488.27	15.06	3.38	1888.25	29.97	15.06	
0.07501	0.63	9.62	489.33	15.41	3.44	1889.05	29.49	15.41	
0.07601	0.63	9.71	490.47	16.07	3.49	1889.90	29.01	16.07	
0.07701	0.63	9.80	491.60	15.36	3.55	1890.82	28.57	15.36	
0.07801	0.63	9.89	492.74	15.15	3.60	1891.72	28.16	15.15	
0.07901	0.63	9.98	493.96	15.63	3.65	1892.63	27.74	15.63	
0.08001	0.63	10.08	495.20	15.56	3.71	1893.60	27.35	15.56	
0.08101	0.63	10.18	496.47	15.48	3.76	1894.60	26.97	15.48	
0.08201	0.63	10.29	497.79	15.65	3.81	1895.61	26.60	15.65	
0.08301	0.63	10.40	499.20	16.37	3.87	1896.67	26.23	16.37	
0.08401	0.63	10.52	500.68	16.67	3.92	1897.80	25.87	16.67	
0.08501	0.63	10.65	502.14	16.03	3.97	1898.98	25.53	16.03	
0.08601	0.63	10.77	503.65	16.20	4.02	1900.15	25.20	16.20	
0.08701	0.63	10.90	505.19	16.15	4.07	1901.36	24.89	16.15	
0.08801	0.63	11.03	506.75	15.97	4.12	1902.59	24.59	15.97	
0.08901	0.63	11.17	508.39	16.39	4.17	1903.84	24.29	16.39	
0.09001	0.63	11.32	510.04	16.19	4.22	1905.16	24.01	16.19	
0.09101	0.63	11.47	511.75	16.40	4.27	1906.48	23.73	16.40	
0.09201	0.63	11.63	513.54	16.79	4.32	1907.86	23.46	16.79	
0.09301	0.63	11.79	515.38	16.90	4.37	1909.29	23.20	16.90	
0.09401	0.63	11.96	517.25	16.81	4.42	1910.77	22.94	16.81	
0.09501	0.63	12.13	519.14	16.69	4.47	1912.27	22.70	16.69	
0.09601	0.63	12.31	521.08	16.75	4.51	1913.79	22.47	16.75	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.09701	0.63	12.50	523.08	17.02	4.56	1915.34	22.23	17.02	
0.09801	0.63	12.70	525.13	17.10	4.61	1916.96	22.01	17.10	
0.09901	0.63	12.90	527.27	17.47	4.65	1918.61	21.79	17.47	
0.10001	0.63	13.11	529.44	17.51	4.70	1920.32	21.58	17.51	
0.10101	0.63	13.33	531.66	17.53	4.74	1922.07	21.37	17.53	
0.10201	0.63	13.56	533.92	17.57	4.79	1923.86	21.17	17.57	
0.10301	0.63	13.79	536.21	17.44	4.83	1925.68	20.98	17.44	
0.10401	0.63	14.03	538.54	17.58	4.88	1927.52	20.79	17.58	
0.03801	0.743	9.47	486.21	24.67	3.22	2080.22	56.12	24.67	90.22
0.03901	0.743	9.61	488.08	25.88	3.32	2081.53	54.34	25.88	
0.04001	0.743	9.77	490.08	26.11	3.42	2082.98	52.69	26.11	
0.04101	0.743	9.93	492.15	25.52	3.52	2084.55	51.19	25.52	
0.04201	0.743	10.11	494.35	25.73	3.62	2086.16	49.79	25.73	
0.04301	0.743	10.30	496.69	25.98	3.72	2087.88	48.48	25.98	
0.04401	0.743	10.51	499.19	26.48	3.82	2089.70	47.24	26.48	
0.04501	0.743	10.73	501.84	26.71	3.92	2091.66	46.07	26.71	
0.04601	0.743	10.97	504.59	26.57	4.01	2093.73	44.99	26.57	
0.04701	0.743	11.21	507.38	25.86	4.10	2095.88	44.01	25.86	
0.04801	0.743	11.48	510.39	26.69	4.19	2098.07	43.06	26.69	
0.04901	0.743	11.77	513.52	26.81	4.28	2100.42	42.17	26.81	
0.05001	0.743	12.07	516.84	27.31	4.37	2102.88	41.32	27.31	
0.05101	0.743	12.39	520.18	26.53	4.45	2105.48	40.55	26.53	
0.05201	0.743	12.74	523.78	27.69	4.53	2108.10	39.79	27.69	
0.05301	0.743	13.11	527.58	28.25	4.62	2110.93	39.07	28.25	
0.05401	0.743	13.50	531.44	27.82	4.70	2113.91	38.40	27.82	
0.05501	0.743	13.91	535.43	27.88	4.78	2116.95	37.77	27.88	
0.05601	0.743	14.35	539.57	28.11	4.85	2120.08	37.18	28.11	
0.05701	0.743	14.81	543.87	28.51	4.93	2123.34	36.61	28.51	
0.02601	0.854	9.43	484.99	32.39	3.15	2247.93	79.48	32.39	125.27
0.02701	0.854	9.62	487.37	30.71	3.29	2249.70	76.16	30.71	
0.02801	0.854	9.84	490.10	32.48	3.43	2251.55	73.01	32.48	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02901	0.854	10.08	493.00	32.01	3.57	2253.65	70.21	32.01	
0.03001	0.854	10.34	496.14	32.27	3.70	2255.89	67.67	32.27	
0.03101	0.854	10.63	499.62	33.41	3.84	2258.32	65.30	33.41	
0.03201	0.854	10.96	503.35	33.60	3.97	2261.00	63.14	33.60	
0.03301	0.854	11.31	507.28	33.48	4.09	2263.86	61.18	33.48	
0.03401	0.854	11.69	511.49	33.90	4.22	2266.90	59.39	33.90	
0.03501	0.854	12.12	516.04	34.70	4.34	2270.15	57.71	34.70	
0.03601	0.854	12.58	520.79	34.59	4.46	2273.65	56.19	34.59	
0.03701	0.854	13.09	525.89	35.36	4.57	2277.33	54.77	35.36	
0.03801	0.854	13.64	531.21	35.42	4.69	2281.25	53.47	35.42	
0.03901	0.854	14.24	536.85	36.00	4.79	2285.37	52.26	36.00	
0.04001	0.854	14.89	542.82	36.66	4.90	2289.73	51.14	36.66	
0.02101	0.951	9.27	484.37	37.33	3.06	2363.52	108.21	37.33	165.56
0.02201	0.951	9.50	487.31	36.97	3.24	2365.60	102.24	36.97	
0.02301	0.951	9.76	490.54	36.84	3.41	2367.90	97.06	36.84	
0.02401	0.951	10.06	494.20	37.85	3.58	2370.45	92.41	37.85	
0.02501	0.951	10.41	498.28	38.79	3.75	2373.31	88.23	38.79	
0.02601	0.951	10.80	502.87	40.04	3.92	2376.51	84.44	40.04	
0.02701	0.951	11.24	507.81	40.04	4.08	2380.07	81.09	40.04	
0.02801	0.951	11.76	513.37	41.99	4.25	2383.95	78.00	41.99	
0.02901	0.951	12.35	519.61	43.96	4.41	2388.31	75.14	43.96	
0.03001	0.951	13.07	526.81	47.61	4.57	2393.22	72.42	47.61	
0.03101	0.951	13.89	534.57	48.22	4.73	2398.81	70.00	48.22	
0.03201	0.951	14.81	542.95	49.33	4.88	2404.83	67.83	49.33	

Appendix B-4 - Camelina Flame Speed Data

DATA SET – I									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Stretch Rate [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.02801	0.72	4.77	484.79	34.46	3.19	2021.49	80.17	34.46	127.76
0.02901	0.72	4.86	487.21	34.62	3.33	2023.24	76.84	34.62	
0.03001	0.72	4.97	489.86	34.89	3.46	2025.13	73.82	34.89	
0.03101	0.72	5.09	492.89	37.09	3.60	2027.21	70.93	37.09	
0.03201	0.72	5.22	496.09	36.48	3.74	2029.58	68.36	36.48	
0.03301	0.72	5.37	499.61	37.65	3.87	2032.09	65.97	37.65	
0.03401	0.72	5.53	503.35	37.43	4.00	2034.85	63.82	37.43	
0.03501	0.72	5.71	507.33	37.62	4.13	2037.78	61.86	37.62	
0.03601	0.72	5.90	511.61	38.37	4.26	2040.91	60.04	38.37	
0.03701	0.72	6.12	516.20	38.94	4.38	2044.28	58.35	38.94	
0.03801	0.72	6.35	520.99	38.76	4.50	2047.88	56.83	38.76	
0.03901	0.72	6.61	526.31	41.09	4.62	2051.66	55.35	41.09	
0.04001	0.72	6.90	531.88	41.16	4.73	2055.85	54.00	41.16	
0.04101	0.72	7.20	537.68	41.14	4.84	2060.24	52.76	41.14	
0.02101	0.812	4.87	486.61	44.62	3.27	2163.78	107.99	44.62	176.76
0.02201	0.812	5.02	490.34	45.59	3.47	2166.31	101.95	45.59	
0.02301	0.812	5.20	494.70	48.07	3.66	2169.21	96.48	48.07	
0.02401	0.812	5.41	499.50	48.07	3.85	2172.58	91.75	48.07	
0.02501	0.812	5.64	504.75	48.26	4.03	2176.29	87.64	48.26	
0.02601	0.812	5.91	510.63	49.96	4.21	2180.36	83.92	49.96	
0.02701	0.812	6.21	516.92	49.66	4.38	2184.90	80.69	49.66	
0.02801	0.812	6.56	523.96	52.03	4.55	2189.78	77.72	52.03	
0.02901	0.812	6.95	531.55	52.71	4.71	2195.23	75.08	52.71	
0.03001	0.812	7.39	539.68	53.36	4.86	2201.11	72.72	53.36	
0.01701	0.898	4.75	484.71	53.00	3.15	2273.65	139.32	53.00	219.23
0.01801	0.898	4.92	488.99	51.80	3.39	2276.60	129.48	51.80	
0.01901	0.898	5.14	494.13	54.64	3.63	2279.97	120.88	54.64	
0.02001	0.898	5.39	500.08	56.32	3.86	2283.98	113.52	56.32	
0.02101	0.898	5.69	506.75	56.75	4.09	2288.60	107.30	56.75	
0.02201	0.898	6.04	514.21	57.86	4.30	2293.76	101.95	57.86	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02301	0.898	6.45	522.66	60.19	4.51	2299.56	97.25	60.19	
0.02401	0.898	6.94	532.06	62.05	4.71	2306.10	93.13	62.05	
0.02501	0.898	7.50	542.19	62.42	4.89	2313.34	89.59	62.42	
0.01601	1.002	4.85	487.28	56.83	3.28	2363.42	152.94	56.83	250.88
0.01701	1.002	5.07	492.63	56.77	3.55	2367.12	141.37	56.77	
0.01801	1.002	5.35	499.09	59.82	3.82	2371.47	131.48	59.82	
0.01901	1.002	5.68	506.43	60.42	4.07	2376.61	123.32	60.42	
0.02001	1.002	6.08	514.89	62.57	4.31	2382.47	116.37	62.57	
0.02101	1.002	6.58	524.84	66.90	4.55	2389.25	110.23	66.90	
0.02201	1.002	7.22	536.58	72.36	4.79	2397.22	104.78	72.36	
DATA SET – II									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Stretch Rate [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.03301	0.693	6.60	484.08	29.65	3.17	1977.33	65.91	29.65	104.54
0.03401	0.693	6.72	486.16	30.94	3.29	1978.79	63.49	30.94	
0.03501	0.693	6.84	488.35	30.53	3.41	1980.42	61.32	30.53	
0.03601	0.693	6.96	490.60	29.54	3.52	1982.15	59.39	29.54	
0.03701	0.693	7.10	493.03	29.97	3.63	1983.93	57.58	29.97	
0.03801	0.693	7.25	495.69	30.96	3.74	1985.85	55.87	30.96	
0.03901	0.693	7.41	498.50	31.03	3.85	1987.94	54.29	31.03	
0.04001	0.693	7.59	501.45	31.01	3.96	1990.16	52.83	31.01	
0.04101	0.693	7.78	504.59	31.35	4.06	1992.50	51.46	31.35	
0.04201	0.693	7.99	508.00	32.39	4.17	1994.98	50.16	32.39	
0.04301	0.693	8.22	511.61	32.87	4.27	1997.67	48.94	32.87	
0.04401	0.693	8.46	515.34	32.58	4.37	2000.53	47.81	32.58	
0.04501	0.693	8.72	519.27	32.85	4.47	2003.49	46.76	32.85	
0.04601	0.693	9.00	523.40	33.26	4.57	2006.61	45.78	33.26	
0.04701	0.693	9.29	527.69	33.28	4.66	2009.89	44.86	33.28	
0.04801	0.693	9.62	532.26	34.22	4.75	2013.30	43.98	34.22	
0.04901	0.693	9.97	537.03	34.51	4.84	2016.93	43.16	34.51	
0.02201	0.798	6.49	483.69	38.89	3.11	2143.86	101.65	38.89	157.86

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02301	0.798	6.66	486.74	41.65	3.29	2145.85	96.08	41.65	
0.02401	0.798	6.84	490.11	41.77	3.46	2148.21	91.22	41.77	
0.02501	0.798	7.05	493.82	41.90	3.63	2150.83	86.95	41.90	
0.02601	0.798	7.29	497.94	42.67	3.80	2153.71	83.12	42.67	
0.02701	0.798	7.55	502.37	42.49	3.96	2156.90	79.76	42.49	
0.02801	0.798	7.85	507.23	43.38	4.12	2160.33	76.72	43.38	
0.02901	0.798	8.19	512.67	45.36	4.27	2164.11	73.89	45.36	
0.03001	0.798	8.57	518.48	45.47	4.42	2168.33	71.37	45.47	
0.03101	0.798	8.99	524.66	45.62	4.57	2172.84	69.12	45.62	
0.03201	0.798	9.46	531.26	46.20	4.71	2177.65	67.09	46.20	
0.03301	0.798	9.98	538.36	47.27	4.84	2182.79	65.22	47.27	
0.01801	0.898	6.52	484.41	47.98	3.12	2278.87	128.43	47.98	200.65
0.01901	0.898	6.74	488.43	49.41	3.35	2281.54	119.66	49.41	
0.02001	0.898	7.00	493.00	49.80	3.57	2284.67	112.26	49.80	
0.02101	0.898	7.30	498.14	50.19	3.79	2288.22	105.96	50.19	
0.02201	0.898	7.65	503.94	51.26	3.99	2292.22	100.49	51.26	
0.02301	0.898	8.07	510.54	53.31	4.20	2296.73	95.62	53.31	
0.02401	0.898	8.55	517.92	54.82	4.39	2301.86	91.34	54.82	
0.02501	0.898	9.10	525.84	54.62	4.58	2307.54	87.67	54.62	
0.02601	0.898	9.74	534.61	56.57	4.76	2313.68	84.39	56.57	
0.02701	0.898	10.50	544.53	60.16	4.93	2320.51	81.38	60.16	
0.01601	1.004	6.54	484.21	50.32	3.08	2371.34	166.10	50.32	255.74
0.01701	1.004	6.80	488.82	54.47	3.35	2374.35	152.77	54.47	
0.01801	1.004	7.11	494.26	55.75	3.61	2378.07	141.73	55.75	
0.01901	1.004	7.50	500.65	57.59	3.86	2382.46	132.41	57.59	
0.02001	1.004	8.00	508.57	63.31	4.12	2387.68	124.01	63.31	
0.02101	1.004	8.63	518.03	67.88	4.38	2394.07	116.66	67.88	
0.02201	1.004	9.40	528.91	70.80	4.63	2401.61	110.42	70.80	
0.02301	1.004	10.32	540.95	72.00	4.86	2410.16	105.22	72.00	

DATA SET – III									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Stretch Rate [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.03501	0.693	10.04	484.58	26.41	3.18	1978.68	58.55	26.41	93.21
0.03601	0.693	10.18	486.34	26.21	3.29	1979.99	56.73	26.21	
0.03701	0.693	10.34	488.27	27.16	3.39	1981.38	55.00	27.16	
0.03801	0.693	10.51	490.31	27.21	3.49	1982.90	53.38	27.21	
0.03901	0.693	10.69	492.40	26.29	3.59	1984.52	51.94	26.29	
0.04001	0.693	10.89	494.74	28.01	3.69	1986.17	50.51	28.01	
0.04101	0.693	11.11	497.23	28.27	3.79	1988.02	49.18	28.27	
0.04201	0.693	11.34	499.81	27.94	3.89	1989.99	47.95	27.94	
0.04301	0.693	11.59	502.55	28.31	3.98	1992.03	46.79	28.31	
0.04401	0.693	11.85	505.41	28.35	4.08	1994.20	45.71	28.35	
0.04501	0.693	12.13	508.39	28.25	4.17	1996.47	44.70	28.25	
0.04601	0.693	12.43	511.56	28.95	4.26	1998.83	43.74	28.95	
0.04701	0.693	12.75	514.86	28.99	4.35	2001.34	42.84	28.99	
0.04801	0.693	13.10	518.36	29.58	4.44	2003.96	41.98	29.58	
0.04901	0.693	13.47	521.95	29.30	4.53	2006.74	41.18	29.30	
0.05001	0.693	13.86	525.70	29.65	4.61	2009.60	40.43	29.65	
0.05101	0.693	14.28	529.66	30.21	4.70	2012.58	39.71	30.21	
0.05201	0.693	14.72	533.74	30.27	4.78	2015.73	39.03	30.27	
0.05301	0.693	15.19	537.96	30.38	4.86	2018.98	38.39	30.38	
0.02501	0.802	10.06	485.02	35.07	3.19	2153.61	83.68	35.07	133.38
0.02601	0.802	10.29	487.69	35.16	3.34	2155.50	79.92	35.16	
0.02701	0.802	10.53	490.61	35.38	3.48	2157.57	76.55	35.38	
0.02801	0.802	10.81	493.85	36.36	3.63	2159.83	73.45	36.36	
0.02901	0.802	11.13	497.40	36.89	3.78	2162.35	70.63	36.89	
0.03001	0.802	11.48	501.23	37.23	3.92	2165.10	68.08	37.23	
0.03101	0.802	11.85	505.29	37.04	4.05	2168.08	65.80	37.04	
0.03201	0.802	12.28	509.71	37.93	4.19	2171.24	63.69	37.93	
0.03301	0.802	12.74	514.41	38.12	4.32	2174.67	61.77	38.12	
0.03401	0.802	13.25	519.43	38.62	4.45	2178.33	60.01	38.62	
0.03501	0.802	13.81	524.79	39.23	4.57	2182.24	58.38	39.23	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03601	0.802	14.42	530.45	39.57	4.69	2186.41	56.90	39.57	
0.03701	0.802	15.09	536.45	40.11	4.80	2190.83	55.53	40.11	
0.03801	0.802	15.84	542.85	41.13	4.92	2195.51	54.25	41.13	
0.02201	0.844	9.94	483.79	38.18	3.11	2213.81	99.89	38.18	155.17
0.02301	0.844	10.18	486.73	38.87	3.28	2215.82	94.60	38.87	
0.02401	0.844	10.46	489.97	38.95	3.45	2218.10	89.97	38.95	
0.02501	0.844	10.77	493.54	39.08	3.61	2220.61	85.88	39.08	
0.02601	0.844	11.13	497.61	41.05	3.78	2223.38	82.10	41.05	
0.02701	0.844	11.53	502.01	41.07	3.94	2226.52	78.75	41.07	
0.02801	0.844	11.97	506.71	40.85	4.09	2229.93	75.80	40.85	
0.02901	0.844	12.47	511.87	41.90	4.25	2233.57	73.11	41.90	
0.03001	0.844	13.03	517.44	42.49	4.39	2237.57	70.67	42.49	
0.03101	0.844	13.67	523.56	44.10	4.54	2241.89	68.41	44.10	
0.03201	0.844	14.38	530.10	44.63	4.68	2246.63	66.37	44.63	
0.03301	0.844	15.19	537.27	46.46	4.81	2251.72	64.47	46.46	
0.02001	0.898	10.01	485.12	42.28	3.18	2285.85	116.57	42.28	185.10
0.02101	0.898	10.31	488.66	42.80	3.37	2288.27	109.78	42.80	
0.02201	0.898	10.65	492.60	43.05	3.56	2291.01	103.92	43.05	
0.02301	0.898	11.05	497.15	44.89	3.75	2294.09	98.64	44.89	
0.02401	0.898	11.51	502.22	45.81	3.94	2297.62	93.97	45.81	
0.02501	0.898	12.05	507.86	46.80	4.12	2301.56	89.83	46.80	
0.02601	0.898	12.69	514.34	49.75	4.30	2305.96	86.01	49.75	
0.02701	0.898	13.45	521.77	52.90	4.49	2311.03	82.48	52.90	
0.02801	0.898	14.35	530.12	55.48	4.67	2316.81	79.29	55.48	
0.02901	0.898	15.40	539.26	56.94	4.84	2323.29	76.45	56.94	
0.01801	0.941	9.87	483.61	46.00	3.05	2333.11	140.26	46.00	213.97
0.01901	0.941	10.18	487.21	45.26	3.27	2335.62	130.92	45.26	
0.02001	0.941	10.54	491.49	47.47	3.49	2338.48	122.67	47.47	
0.02101	0.941	10.99	496.51	49.71	3.71	2341.87	115.40	49.71	
0.02201	0.941	11.55	502.60	53.97	3.94	2345.87	108.74	53.97	
0.02301	0.941	12.23	509.65	56.48	4.16	2350.67	102.89	56.48	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02401	0.941	13.02	517.55	57.68	4.37	2356.19	97.85	57.68	
0.02501	0.941	13.96	526.38	59.50	4.58	2362.36	93.45	59.50	
0.02601	0.941	15.03	535.93	59.75	4.77	2369.22	89.70	59.75	
0.02701	0.941	16.28	546.38	61.32	4.95	2376.65	86.40	61.32	
0.01801	0.991	10.28	488.71	52.16	3.31	2377.97	70.32	52.16	233.11
0.01901	0.991	10.74	494.00	55.20	3.57	2381.50	65.22	55.20	
0.02001	0.991	11.33	500.51	59.40	3.84	2385.81	60.73	59.40	
0.02101	0.991	12.02	507.81	59.36	4.08	2390.96	57.07	59.36	
0.02201	0.991	12.84	515.96	59.86	4.32	2396.73	54.00	59.86	
0.02301	0.991	13.81	525.14	61.68	4.54	2403.17	51.36	61.68	
0.02401	0.991	14.93	535.10	61.77	4.74	2410.36	49.14	61.77	
0.02501	0.991	16.29	546.45	65.67	4.94	2418.25	47.15	65.67	

Appendix B-5 - Camelina – JP-8 Flame Speed Data

DATA SET – I									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Stretch Rate [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.03501	0.711	4.68	482.50	27.66	3.06	2026.59	65.75	27.66	100.64
0.03601	0.711	4.75	484.36	28.80	3.18	2027.89	63.32	28.80	
0.03701	0.711	4.83	486.25	27.39	3.29	2029.34	61.22	27.39	
0.03801	0.711	4.90	488.15	25.90	3.39	2030.81	59.38	25.90	
0.03901	0.711	4.99	490.33	28.11	3.50	2032.30	57.54	28.11	
0.04001	0.711	5.09	492.80	29.90	3.61	2034.01	55.74	29.90	
0.04101	0.711	5.20	495.39	29.66	3.72	2035.94	54.09	29.66	
0.04201	0.711	5.31	498.01	28.43	3.82	2037.97	52.64	28.43	
0.04301	0.711	5.43	500.89	29.74	3.93	2040.02	51.23	29.74	
0.04401	0.711	5.55	503.76	28.28	4.03	2042.27	49.99	28.28	
0.04501	0.711	5.70	507.11	31.46	4.13	2044.53	48.70	31.46	
0.04601	0.711	5.86	510.55	30.89	4.23	2047.16	47.54	30.89	
0.04701	0.711	6.02	514.08	30.31	4.33	2049.86	46.48	30.31	
0.04801	0.711	6.19	517.70	30.01	4.42	2052.62	45.50	30.01	
0.04901	0.711	6.38	521.76	32.29	4.52	2055.48	44.52	32.29	
0.05001	0.711	6.59	525.96	32.19	4.62	2058.67	43.62	32.19	
0.05101	0.711	6.82	530.41	32.93	4.71	2061.97	42.75	32.93	
0.05201	0.711	7.05	534.90	32.07	4.80	2065.48	41.97	32.07	
0.05301	0.711	7.30	539.60	32.58	4.88	2069.01	41.23	32.58	
0.05401	0.711	7.57	544.52	33.10	4.97	2072.72	40.53	33.10	
0.02501	0.809	4.81	484.37	34.96	3.17	2181.81	88.10	34.96	139.49
0.02601	0.809	4.91	486.94	33.84	3.31	2183.68	84.19	33.84	
0.02701	0.809	5.03	490.00	36.79	3.47	2185.68	80.41	36.79	
0.02801	0.809	5.17	493.38	37.46	3.62	2188.04	76.99	37.46	
0.02901	0.809	5.33	497.08	37.97	3.78	2190.64	73.90	37.97	
0.03001	0.809	5.50	501.05	37.89	3.92	2193.49	71.15	37.89	
0.03101	0.809	5.70	505.38	38.63	4.06	2196.55	68.63	38.63	
0.03201	0.809	5.91	510.10	39.56	4.21	2199.88	66.32	39.56	
0.03301	0.809	6.15	515.04	39.03	4.34	2203.51	64.27	39.03	
0.03401	0.809	6.41	520.44	40.41	4.47	2207.33	62.35	40.41	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03501	0.809	6.71	526.34	41.92	4.61	2211.50	60.56	41.92	
0.03601	0.809	7.03	532.47	41.50	4.73	2216.05	58.96	41.50	
0.03701	0.809	7.38	538.88	41.53	4.85	2220.78	57.51	41.53	
0.03801	0.809	7.78	545.79	42.91	4.97	2225.75	56.15	42.91	
0.02001	0.899	4.79	483.59	42.24	3.09	2299.94	114.97	42.24	177.52
0.02101	0.899	4.92	486.88	41.46	3.28	2302.23	108.15	41.46	
0.02201	0.899	5.08	490.71	43.36	3.48	2304.80	102.04	43.36	
0.02301	0.899	5.26	495.01	43.86	3.67	2307.77	96.73	43.86	
0.02401	0.899	5.47	499.89	45.32	3.86	2311.10	91.98	45.32	
0.02501	0.899	5.71	505.21	45.36	4.04	2314.86	87.86	45.36	
0.02601	0.899	5.99	511.03	45.91	4.22	2318.96	84.22	45.91	
0.02701	0.899	6.30	517.38	46.59	4.38	2323.44	80.99	46.59	
0.02801	0.899	6.65	524.47	48.66	4.55	2328.35	78.03	48.66	
0.02901	0.899	7.05	532.00	48.63	4.71	2333.78	75.43	48.63	
0.03001	0.899	7.50	539.99	48.83	4.86	2339.55	73.13	48.83	
0.01801	1.009	4.77	483.82	43.97	3.09	2391.49	128.75	43.97	199.12
0.01901	1.009	4.92	487.57	44.42	3.31	2394.10	120.22	44.42	
0.02001	1.009	5.11	491.92	45.77	3.53	2397.11	112.82	45.77	
0.02101	1.009	5.33	497.01	47.87	3.75	2400.61	106.27	47.87	
0.02201	1.009	5.58	502.58	47.31	3.95	2404.61	100.79	47.31	
0.02301	1.009	5.88	509.03	49.96	4.16	2409.07	95.84	49.96	
0.02401	1.009	6.21	515.83	48.56	4.34	2414.07	91.71	48.56	
0.02501	1.009	6.61	523.61	51.47	4.53	2419.48	87.93	51.47	
0.02601	1.009	7.07	532.16	52.80	4.71	2425.57	84.59	52.80	
0.02701	1.009	7.61	541.69	55.27	4.88	2432.29	81.57	55.27	
DATA SET – II									
0.04101	0.695	6.48	484.07	22.74	3.18	2001.78	53.52	22.74	84.98
0.04201	0.695	6.57	485.80	25.55	3.28	2002.91	51.88	25.55	
0.04301	0.695	6.67	487.59	25.00	3.37	2004.27	50.39	25.00	
0.04401	0.695	6.77	489.43	24.46	3.47	2005.67	49.03	24.46	
0.04501	0.695	6.87	491.35	24.33	3.56	2007.12	47.78	24.33	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.04601	0.695	6.98	493.39	24.46	3.65	2008.63	46.59	24.46	
0.04701	0.695	7.10	495.53	24.60	3.74	2010.23	45.48	24.60	
0.04801	0.695	7.24	497.88	25.82	3.83	2011.92	44.39	25.82	
0.04901	0.695	7.38	500.24	24.86	3.92	2013.77	43.41	24.86	
0.05001	0.695	7.52	502.71	24.92	4.00	2015.63	42.49	24.92	
0.05101	0.695	7.68	505.32	25.38	4.09	2017.57	41.60	25.38	
0.05201	0.695	7.84	508.04	25.43	4.17	2019.63	40.77	25.43	
0.05301	0.695	8.03	511.04	27.03	4.26	2021.78	39.94	27.03	
0.05401	0.695	8.22	514.11	26.60	4.34	2024.15	39.17	26.60	
0.05501	0.695	8.42	517.31	26.88	4.42	2026.57	38.44	26.88	
0.05601	0.695	8.64	520.53	26.19	4.50	2029.09	37.77	26.19	
0.05701	0.695	8.86	523.94	26.85	4.58	2031.64	37.13	26.85	
0.05801	0.695	9.11	527.50	27.18	4.65	2034.34	36.52	27.18	
0.05901	0.695	9.36	531.18	27.35	4.73	2037.16	35.93	27.35	
0.06001	0.695	9.63	535.01	27.62	4.80	2040.07	35.38	27.62	
0.06101	0.695	9.92	538.98	27.90	4.88	2043.11	34.85	27.90	
0.02701	0.798	6.44	483.16	31.22	3.09	2167.01	81.45	31.22	125.75
0.02801	0.798	6.56	485.44	31.78	3.23	2168.60	77.95	31.78	
0.02901	0.798	6.70	488.07	33.65	3.37	2170.37	74.63	33.65	
0.03001	0.798	6.86	490.95	34.13	3.51	2172.40	71.62	34.13	
0.03101	0.798	7.02	493.83	31.75	3.64	2174.61	69.09	31.75	
0.03201	0.798	7.21	497.15	34.26	3.78	2176.84	66.62	34.26	
0.03301	0.798	7.42	500.63	33.68	3.90	2179.40	64.42	33.68	
0.03401	0.798	7.64	504.37	34.09	4.03	2182.09	62.40	34.09	
0.03501	0.798	7.89	508.43	34.98	4.16	2184.98	60.51	34.98	
0.03601	0.798	8.17	512.77	35.45	4.28	2188.12	58.77	35.45	
0.03701	0.798	8.47	517.49	36.61	4.40	2191.49	57.14	36.61	
0.03801	0.798	8.79	522.24	35.14	4.52	2195.13	55.70	35.14	
0.03901	0.798	9.15	527.39	36.43	4.63	2198.82	54.35	36.43	
0.04001	0.798	9.53	532.85	37.05	4.74	2202.81	53.08	37.05	
0.04101	0.798	9.95	538.54	37.12	4.84	2207.04	51.92	37.12	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02201	0.902	6.44	485.62	36.82	3.20	2309.81	97.92	36.82	156.72
0.02301	0.902	6.61	488.93	39.37	3.38	2312.00	92.67	39.37	
0.02401	0.902	6.82	492.61	39.64	3.56	2314.57	88.07	39.64	
0.02501	0.902	7.04	496.55	38.84	3.73	2317.39	84.13	38.84	
0.02601	0.902	7.30	500.97	40.17	3.89	2320.44	80.54	40.17	
0.02701	0.902	7.59	505.75	40.27	4.05	2323.85	77.36	40.27	
0.02801	0.902	7.92	511.16	42.52	4.21	2327.56	74.39	42.52	
0.02901	0.902	8.30	516.96	42.56	4.37	2331.72	71.76	42.56	
0.03001	0.902	8.70	522.99	41.70	4.51	2336.15	69.47	41.70	
0.03101	0.902	9.16	529.64	43.56	4.66	2340.82	67.33	43.56	
0.03201	0.902	9.67	536.69	43.82	4.79	2345.93	65.42	43.82	
0.03301	0.902	10.24	544.25	44.84	4.92	2351.36	63.66	44.84	
0.01901	0.991	6.38	484.01	39.76	3.08	2390.70	120.92	39.76	186.44
0.02001	0.991	6.56	487.49	41.80	3.29	2393.06	113.36	41.80	
0.02101	0.991	6.79	491.53	43.31	3.49	2395.84	106.69	43.31	
0.02201	0.991	7.04	495.84	41.83	3.69	2398.99	101.19	41.83	
0.02301	0.991	7.33	500.84	44.06	3.88	2402.44	96.18	44.06	
0.02401	0.991	7.67	506.28	43.95	4.06	2406.35	91.85	43.95	
0.02501	0.991	8.06	512.51	46.40	4.24	2410.67	87.88	46.40	
0.02601	0.991	8.53	519.52	48.49	4.42	2415.59	84.29	48.49	
0.02701	0.991	9.08	527.45	51.05	4.60	2421.13	81.00	51.05	
0.02801	0.991	9.74	536.51	54.64	4.78	2427.41	77.97	54.64	
0.02901	0.991	10.53	546.69	57.70	4.96	2434.54	75.22	57.70	

DATA SET – III

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.04401	0.694	8.08	483.13	20.14	3.11	1999.97	47.44	20.14	73.85
0.04501	0.694	8.17	484.46	20.73	3.20	2000.94	46.22	20.73	
0.04601	0.694	8.26	485.89	21.19	3.28	2001.99	45.05	21.19	
0.04701	0.694	8.36	487.32	20.13	3.36	2003.11	44.01	20.13	
0.04801	0.694	8.46	488.78	19.85	3.43	2004.23	43.04	19.85	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.04901	0.694	8.57	490.34	20.17	3.51	2005.39	42.11	20.17	
0.05001	0.694	8.68	492.02	20.98	3.59	2006.61	41.19	20.98	
0.05101	0.694	8.81	493.76	20.82	3.66	2007.94	40.33	20.82	
0.05201	0.694	8.94	495.64	21.56	3.74	2009.31	39.49	21.56	
0.05301	0.694	9.08	497.65	22.14	3.82	2010.79	38.68	22.14	
0.05401	0.694	9.23	499.69	21.69	3.89	2012.37	37.93	21.69	
0.05501	0.694	9.40	501.93	22.99	3.97	2013.98	37.18	22.99	
0.05601	0.694	9.57	504.29	23.23	4.05	2015.75	36.46	23.23	
0.05701	0.694	9.76	506.76	23.54	4.13	2017.61	35.77	23.54	
0.05801	0.694	9.95	509.32	23.52	4.21	2019.56	35.12	23.52	
0.05901	0.694	10.16	511.91	23.08	4.28	2021.58	34.52	23.08	
0.06001	0.694	10.37	514.55	22.85	4.35	2023.62	33.96	22.85	
0.06101	0.694	10.59	517.31	23.13	4.42	2025.72	33.41	23.13	
0.06201	0.694	10.83	520.19	23.48	4.49	2027.90	32.89	23.48	
0.06301	0.694	11.07	523.12	23.23	4.56	2030.18	32.40	23.23	
0.06401	0.694	11.33	526.15	23.42	4.63	2032.50	31.93	23.42	
0.06501	0.694	11.60	529.24	23.25	4.69	2034.90	31.49	23.25	
0.06601	0.694	11.88	532.47	23.80	4.76	2037.35	31.06	23.80	
0.06701	0.694	12.19	535.89	24.48	4.82	2039.92	30.64	24.48	
0.06801	0.694	12.50	539.33	24.15	4.88	2042.62	30.25	24.15	
0.06901	0.694	12.84	542.88	24.31	4.94	2045.36	29.87	24.31	
0.02801	0.808	8.15	485.05	31.04	3.13	2184.97	74.06	31.04	115.97
0.02901	0.808	8.30	487.29	30.29	3.26	2186.60	71.07	30.29	
0.03001	0.808	8.47	489.74	30.65	3.39	2188.34	68.34	30.65	
0.03101	0.808	8.65	492.42	31.31	3.52	2190.23	65.81	31.31	
0.03201	0.808	8.87	495.44	32.78	3.66	2192.30	63.42	32.78	
0.03301	0.808	9.08	498.40	30.29	3.78	2194.62	61.41	30.29	
0.03401	0.808	9.32	501.66	31.36	3.90	2196.91	59.51	31.36	
0.03501	0.808	9.60	505.29	32.99	4.02	2199.44	57.68	32.99	
0.03601	0.808	9.89	509.09	32.75	4.14	2202.24	56.03	32.75	
0.03701	0.808	10.20	513.04	32.27	4.25	2205.18	54.54	32.27	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03801	0.808	10.55	517.35	33.64	4.37	2208.23	53.11	33.64	
0.03901	0.808	10.93	521.83	33.34	4.48	2211.57	51.81	33.34	
0.04001	0.808	11.33	526.50	33.41	4.58	2215.03	50.62	33.41	
0.04101	0.808	11.77	531.48	34.10	4.69	2218.66	49.50	34.10	
0.04201	0.808	12.25	536.80	35.18	4.79	2222.52	48.43	35.18	
0.04301	0.808	12.77	542.28	34.88	4.89	2226.65	47.46	34.88	
0.04401	0.808	13.33	548.01	35.23	4.98	2230.91	46.55	35.23	
0.02201	0.913	8.21	485.27	36.46	3.11	2326.56	97.47	36.46	151.68
0.02301	0.913	8.41	488.23	36.78	3.29	2328.61	92.34	36.78	
0.02401	0.913	8.64	491.44	36.43	3.45	2330.90	87.90	36.43	
0.02501	0.913	8.91	495.14	38.22	3.62	2333.41	83.80	38.22	
0.02601	0.913	9.19	499.04	37.16	3.78	2336.25	80.29	37.16	
0.02701	0.913	9.53	503.45	38.92	3.94	2339.28	77.03	38.92	
0.02801	0.913	9.91	508.32	39.97	4.10	2342.70	74.06	39.97	
0.02901	0.913	10.32	513.39	38.90	4.24	2346.43	71.50	38.90	
0.03001	0.913	10.79	518.97	40.33	4.39	2350.36	69.12	40.33	
0.03101	0.913	11.30	524.97	40.86	4.53	2354.66	66.97	40.86	
0.03201	0.913	11.89	531.45	41.88	4.67	2359.29	65.00	41.88	
0.03301	0.913	12.54	538.38	42.64	4.80	2364.29	63.20	42.64	
0.03401	0.913	13.28	545.91	44.17	4.93	2369.66	61.53	44.17	
0.01901	1.006	8.08	484.86	39.11	3.04	2405.37	128.69	39.11	195.69
0.02001	1.006	8.30	488.11	40.10	3.24	2407.62	120.77	40.10	
0.02101	1.006	8.56	491.81	40.72	3.44	2410.22	113.89	40.72	
0.02201	1.006	8.89	496.31	44.36	3.64	2413.24	107.47	44.36	
0.02301	1.006	9.28	501.52	46.33	3.85	2416.84	101.74	46.33	
0.02401	1.006	9.76	507.80	50.60	4.06	2421.06	96.41	50.60	
0.02501	1.006	10.32	514.60	50.21	4.26	2425.97	91.90	50.21	
0.02601	1.006	10.97	522.25	52.06	4.45	2431.36	87.90	52.06	
0.02701	1.006	11.70	530.45	51.88	4.63	2437.33	84.47	51.88	
0.02801	1.006	12.54	539.44	53.35	4.81	2443.76	81.42	53.35	
0.02901	1.006	13.49	548.97	53.31	4.97	2450.74	78.77	53.31	

DATA SET – IV									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Stretch Rate [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.04301	0.714	9.90	483.05	19.70	3.07	2034.37	47.88	19.70	73.61
0.04401	0.714	10.01	484.34	20.01	3.16	2035.31	46.65	20.01	
0.04501	0.714	10.12	485.72	20.55	3.24	2036.32	45.46	20.55	
0.04601	0.714	10.24	487.19	20.73	3.32	2037.40	44.34	20.73	
0.04701	0.714	10.37	488.74	20.95	3.40	2038.55	43.28	20.95	
0.04801	0.714	10.51	490.34	20.73	3.48	2039.77	42.29	20.73	
0.04901	0.714	10.65	492.04	20.92	3.56	2041.03	41.34	20.92	
0.05001	0.714	10.80	493.78	20.63	3.64	2042.35	40.47	20.63	
0.05101	0.714	10.96	495.66	21.43	3.72	2043.72	39.61	21.43	
0.05201	0.714	11.14	497.63	21.55	3.79	2045.20	38.79	21.55	
0.05301	0.714	11.32	499.72	22.00	3.87	2046.75	38.01	22.00	
0.05401	0.714	11.52	501.84	21.49	3.95	2048.39	37.28	21.49	
0.05501	0.714	11.72	504.01	21.37	4.02	2050.05	36.60	21.37	
0.05601	0.714	11.93	506.34	22.02	4.10	2051.77	35.93	22.02	
0.05701	0.714	12.15	508.70	21.60	4.17	2053.59	35.32	21.60	
0.05801	0.714	12.40	511.24	22.61	4.24	2055.45	34.70	22.61	
0.05901	0.714	12.65	513.83	22.27	4.31	2057.46	34.13	22.27	
0.06001	0.714	12.91	516.48	22.12	4.38	2059.49	33.59	22.12	
0.06101	0.714	13.19	519.30	22.91	4.45	2061.58	33.06	22.91	
0.06201	0.714	13.49	522.20	22.85	4.52	2063.81	32.56	22.85	
0.06301	0.714	13.80	525.20	23.06	4.59	2066.09	32.08	23.06	
0.06401	0.714	14.13	528.28	23.04	4.66	2068.46	31.62	23.04	
0.06501	0.714	14.47	531.41	22.90	4.72	2070.89	31.19	22.90	
0.06601	0.714	14.83	534.69	23.40	4.78	2073.37	30.78	23.40	
0.06701	0.714	15.20	538.04	23.29	4.85	2075.97	30.38	23.29	
0.06801	0.714	15.61	541.55	23.91	4.91	2078.62	29.99	23.91	
0.02901	0.811	9.89	484.00	27.95	3.06	2190.24	70.17	27.95	107.33
0.03001	0.811	10.05	485.95	27.62	3.18	2191.65	67.49	27.62	
0.03101	0.811	10.22	488.08	28.03	3.30	2193.16	65.01	28.03	
0.03201	0.811	10.42	490.40	28.46	3.42	2194.80	62.72	28.46	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03301	0.811	10.63	492.86	28.29	3.54	2196.59	60.64	28.29	
0.03401	0.811	10.86	495.48	28.40	3.65	2198.49	58.73	28.40	
0.03501	0.811	11.11	498.37	29.49	3.77	2200.51	56.92	29.49	
0.03601	0.811	11.39	501.45	29.76	3.89	2202.75	55.23	29.76	
0.03701	0.811	11.69	504.65	29.31	4.00	2205.13	53.71	29.31	
0.03801	0.811	12.01	508.04	29.47	4.10	2207.60	52.30	29.47	
0.03901	0.811	12.36	511.68	30.27	4.21	2210.22	50.97	30.27	
0.04001	0.811	12.73	515.51	30.35	4.32	2213.05	49.73	30.35	
0.04101	0.811	13.14	519.54	30.61	4.42	2216.01	48.58	30.61	
0.04201	0.811	13.59	523.84	31.40	4.52	2219.13	47.49	31.40	
0.04301	0.811	14.06	528.28	31.11	4.62	2222.47	46.49	31.11	
0.04401	0.811	14.56	532.90	31.24	4.71	2225.91	45.56	31.24	
0.04501	0.811	15.11	537.79	31.97	4.80	2229.50	44.68	31.97	
0.04601	0.811	15.71	542.94	32.54	4.90	2233.30	43.84	32.54	
0.04701	0.811	16.35	548.31	32.88	4.98	2237.31	43.06	32.88	
0.02401	0.908	10.15	486.77	35.05	3.16	2325.03	91.06	35.05	143.75
0.02501	0.908	10.39	489.63	35.04	3.32	2327.04	86.60	35.04	
0.02601	0.908	10.67	492.78	35.15	3.48	2329.26	82.65	35.15	
0.02701	0.908	10.97	496.25	35.65	3.63	2331.70	79.10	35.65	
0.02801	0.908	11.33	500.14	37.00	3.79	2334.39	75.83	37.00	
0.02901	0.908	11.71	504.29	36.57	3.94	2337.39	72.96	36.57	
0.03001	0.908	12.14	508.72	36.53	4.08	2340.59	70.39	36.53	
0.03101	0.908	12.61	513.46	36.76	4.22	2344.00	68.07	36.76	
0.03201	0.908	13.13	518.56	37.35	4.36	2347.66	65.95	37.35	
0.03301	0.908	13.72	524.20	39.03	4.49	2351.62	63.96	39.03	
0.03401	0.908	14.38	530.23	39.61	4.63	2355.97	62.14	39.61	
0.03501	0.908	15.13	536.84	41.32	4.76	2360.65	60.44	41.32	
0.03601	0.908	16.00	544.21	44.00	4.89	2365.78	58.81	44.00	
0.02101	1.005	10.16	488.32	37.44	3.20	2412.64	115.23	37.44	184.60
0.02201	1.005	10.46	491.83	39.42	3.39	2415.05	108.76	39.42	
0.02301	1.005	10.82	495.89	41.14	3.59	2417.86	102.94	41.14	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02401	1.005	11.25	500.64	43.52	3.78	2421.12	97.64	43.52	
0.02501	1.005	11.77	506.11	45.69	3.98	2424.92	92.84	45.69	
0.02601	1.005	12.37	512.30	47.32	4.17	2429.26	88.56	47.32	
0.02701	1.005	13.06	519.03	47.61	4.35	2434.12	84.84	47.61	
0.02801	1.005	13.84	526.39	48.39	4.53	2439.40	81.56	48.39	
0.02901	1.005	14.71	534.18	48.10	4.69	2445.13	78.72	48.10	
0.03001	1.005	15.71	542.61	49.08	4.85	2451.22	76.17	49.08	

Appendix B-6 - HRJ Flame Speed Data

DATA SET – I									
Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.04201	0.695	4.87	486.38	25.47	3.27	1986.23	55.84	25.47	91.43
0.04301	0.695	4.94	488.24	26.26	3.38	1987.56	54.17	26.26	
0.04401	0.695	5.02	490.17	25.70	3.47	1989.02	52.66	25.70	
0.04501	0.695	5.10	492.16	25.34	3.57	1990.54	51.27	25.34	
0.04601	0.695	5.19	494.37	26.64	3.66	1992.11	49.91	26.64	
0.04701	0.695	5.29	496.88	28.74	3.77	1993.85	48.55	28.74	
0.04801	0.695	5.40	499.39	27.47	3.86	1995.82	47.34	27.47	
0.04901	0.695	5.51	502.01	27.28	3.96	1997.80	46.22	27.28	
0.05001	0.695	5.64	504.80	27.84	4.05	1999.87	45.15	27.84	
0.05101	0.695	5.76	507.68	27.61	4.14	2002.06	44.17	27.61	
0.05201	0.695	5.90	510.73	28.13	4.23	2004.34	43.22	28.13	
0.05301	0.695	6.05	513.91	28.16	4.32	2006.75	42.34	28.16	
0.05401	0.695	6.21	517.30	28.97	4.41	2009.26	41.49	28.97	
0.05501	0.695	6.38	520.82	28.90	4.49	2011.94	40.70	28.90	
0.05601	0.695	6.56	524.54	29.67	4.58	2014.72	39.94	29.67	
0.05701	0.695	6.76	528.36	29.45	4.66	2017.66	39.23	29.45	
0.05801	0.695	6.97	532.45	30.57	4.74	2020.69	38.54	30.57	
0.05901	0.695	7.19	536.64	30.35	4.82	2023.93	37.90	30.35	
0.02601	0.803	4.78	484.04	35.33	3.12	2154.35	85.43	35.33	133.18
0.02701	0.803	4.88	486.54	34.25	3.27	2156.16	81.56	34.25	
0.02801	0.803	4.99	489.30	34.84	3.41	2158.08	78.05	34.84	
0.02901	0.803	5.12	492.35	35.50	3.56	2160.22	74.86	35.50	
0.03001	0.803	5.26	495.80	37.27	3.71	2162.58	71.85	37.27	
0.03101	0.803	5.42	499.38	35.91	3.85	2165.24	69.26	35.91	
0.03201	0.803	5.59	503.22	36.20	3.98	2167.99	66.90	36.20	
0.03301	0.803	5.78	507.45	37.48	4.12	2170.97	64.70	37.48	
0.03401	0.803	5.99	512.05	38.36	4.25	2174.24	62.66	38.36	
0.03501	0.803	6.22	516.82	37.69	4.38	2177.78	60.85	37.69	
0.03601	0.803	6.48	522.12	39.78	4.51	2181.48	59.12	39.78	
0.03701	0.803	6.77	527.76	40.31	4.63	2185.58	57.53	40.31	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03801	0.803	7.08	533.65	40.24	4.75	2189.94	56.09	40.24	
0.03901	0.803	7.42	539.89	40.80	4.86	2194.51	54.76	40.80	
0.04001	0.803	7.79	546.46	41.36	4.98	2199.34	53.53	41.36	
0.02101	0.896	4.82	485.01	40.61	3.17	2277.55	107.16	40.61	169.91
0.02201	0.896	4.96	488.41	41.57	3.36	2279.86	101.10	41.57	
0.02301	0.896	5.11	492.20	41.84	3.55	2282.50	95.83	41.84	
0.02401	0.896	5.30	496.61	44.14	3.73	2285.46	91.01	44.14	
0.02501	0.896	5.51	501.41	43.95	3.91	2288.86	86.84	43.95	
0.02601	0.896	5.75	506.61	44.03	4.08	2292.55	83.19	44.03	
0.02701	0.896	6.02	512.35	45.06	4.25	2296.57	79.91	45.06	
0.02801	0.896	6.32	518.55	45.48	4.41	2300.98	77.00	45.48	
0.02901	0.896	6.67	525.39	47.09	4.57	2305.77	74.34	47.09	
0.03001	0.896	7.06	532.76	47.91	4.72	2311.03	71.95	47.91	
0.03101	0.896	7.49	540.49	47.67	4.87	2316.68	69.84	47.67	
0.01901	1	4.87	487.68	46.76	3.29	2368.75	118.42	46.76	195.04
0.02001	1	5.05	491.91	45.55	3.51	2371.78	111.19	45.55	
0.02101	1	5.26	496.90	48.14	3.73	2375.18	104.72	48.14	
0.02201	1	5.50	502.34	47.43	3.93	2379.11	99.30	47.43	
0.02301	1	5.79	508.64	49.97	4.13	2383.45	94.42	49.97	
0.02401	1	6.10	515.25	48.39	4.32	2388.33	90.36	48.39	
0.02501	1	6.49	522.91	51.92	4.50	2393.60	86.60	51.92	
0.02601	1	6.93	531.30	53.07	4.68	2399.60	83.28	53.07	
0.02701	1	7.43	540.23	53.07	4.85	2406.11	80.41	53.07	
DATA SET – II									
0.05701	0.699	8.16	515.41	26.91	4.34	2015.42	35.53	26.91	77.15
0.05801	0.699	8.37	518.59	26.95	4.42	2017.85	34.87	26.95	
0.05901	0.699	8.58	521.92	27.29	4.51	2020.36	34.25	27.29	
0.06001	0.699	8.81	525.33	27.03	4.58	2023.00	33.66	27.03	
0.06101	0.699	9.04	528.85	27.10	4.66	2025.69	33.11	27.10	
0.06201	0.699	9.30	532.57	27.80	4.74	2028.49	32.58	27.80	
0.06301	0.699	9.57	536.37	27.59	4.81	2031.44	32.08	27.59	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.06401	0.699	9.85	540.31	27.86	4.88	2034.45	31.60	27.86	
0.02901	0.791	6.50	484.46	30.96	3.20	2139.05	72.74	30.96	116.42
0.03001	0.791	6.63	486.83	31.45	3.33	2140.72	69.84	31.45	
0.03101	0.791	6.77	489.40	31.72	3.46	2142.55	67.20	31.72	
0.03201	0.791	6.93	492.16	31.74	3.59	2144.54	64.81	31.74	
0.03301	0.791	7.09	495.10	31.72	3.72	2146.67	62.64	31.72	
0.03401	0.791	7.27	498.25	31.98	3.84	2148.95	60.64	31.98	
0.03501	0.791	7.48	501.66	32.64	3.96	2151.39	58.78	32.64	
0.03601	0.791	7.69	505.28	32.79	4.08	2154.03	57.07	32.79	
0.03701	0.791	7.94	509.21	33.77	4.20	2156.84	55.46	33.77	
0.03801	0.791	8.20	513.40	34.28	4.31	2159.89	53.97	34.28	
0.03901	0.791	8.49	517.81	34.32	4.43	2163.14	52.60	34.32	
0.04001	0.791	8.79	522.36	33.99	4.53	2166.55	51.35	33.99	
0.04101	0.791	9.13	527.26	35.01	4.64	2170.10	50.17	35.01	
0.04201	0.791	9.50	532.45	35.70	4.75	2173.91	49.06	35.70	
0.04301	0.791	9.89	537.82	35.54	4.85	2177.94	48.05	35.54	
0.04401	0.791	10.32	543.49	36.28	4.94	2182.12	47.09	36.28	
0.02301	0.896	6.62	486.98	37.87	3.28	2283.92	92.62	37.87	151.76
0.02401	0.896	6.81	490.39	39.40	3.45	2286.23	87.88	39.40	
0.02501	0.896	7.02	494.07	38.85	3.62	2288.85	83.79	38.85	
0.02601	0.896	7.25	498.08	38.96	3.79	2291.69	80.18	38.96	
0.02701	0.896	7.52	502.53	40.00	3.95	2294.80	76.91	40.00	
0.02801	0.896	7.82	507.41	40.78	4.10	2298.24	73.95	40.78	
0.02901	0.896	8.16	512.73	41.51	4.26	2302.01	71.28	41.51	
0.03001	0.896	8.53	518.41	41.67	4.41	2306.10	68.89	41.67	
0.03101	0.896	8.95	524.44	41.77	4.55	2310.47	66.76	41.77	
0.03201	0.896	9.41	530.98	42.94	4.68	2315.13	64.79	42.94	
0.03301	0.896	9.93	537.94	43.49	4.82	2320.17	63.01	43.49	
0.03401	0.896	10.51	545.43	44.70	4.95	2325.54	61.37	44.70	
0.02001	0.996	6.57	487.11	40.84	3.25	2549.43	111.25	40.84	180.76
0.02101	0.996	6.80	491.06	42.23	3.46	2549.51	104.61	42.23	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02201	0.996	7.04	495.29	41.01	3.65	2549.60	99.14	41.01	
0.02301	0.996	7.33	500.15	43.02	3.84	2549.71	94.20	43.02	
0.02401	0.996	7.65	505.38	42.85	4.02	2549.82	89.96	42.85	
0.02501	0.996	8.03	511.47	44.09	4.20	2575.36	86.05	44.09	
0.02601	0.996	8.47	518.12	44.67	4.38	2575.51	82.61	44.67	
0.02701	0.996	8.97	525.33	45.40	4.54	2575.66	79.56	45.40	
0.02801	0.996	9.58	533.67	49.27	4.71	2575.84	76.69	49.27	
0.02901	0.996	10.29	543.02	56.74	4.89	2414.23	73.98	56.74	
DATA SET – III									
0.04501	0.7	8.19	485.16	21.20	3.20	1995.14	46.57	21.20	74.60
0.04601	0.7	8.29	486.61	21.35	3.29	1996.21	45.39	21.35	
0.04701	0.7	8.39	488.12	21.29	3.37	1997.35	44.29	21.29	
0.04801	0.7	8.50	489.68	21.11	3.45	1998.54	43.26	21.11	
0.04901	0.7	8.61	491.37	21.66	3.53	1999.77	42.27	21.66	
0.05001	0.7	8.74	493.13	21.72	3.61	2001.10	41.33	21.72	
0.05101	0.7	8.87	495.00	22.13	3.69	2002.49	40.43	22.13	
0.05201	0.7	9.01	496.94	21.97	3.77	2003.96	39.59	21.97	
0.05301	0.7	9.15	498.94	21.97	3.85	2005.49	38.79	21.97	
0.05401	0.7	9.31	501.07	22.37	3.92	2007.07	38.03	22.37	
0.05501	0.7	9.48	503.39	23.56	4.00	2008.75	37.27	23.56	
0.05601	0.7	9.65	505.69	22.47	4.08	2010.58	36.58	22.47	
0.05701	0.7	9.84	508.17	23.41	4.16	2012.40	35.91	23.41	
0.05801	0.7	10.04	510.70	23.18	4.23	2014.35	35.28	23.18	
0.05901	0.7	10.24	513.28	22.87	4.30	2016.35	34.69	22.87	
0.06001	0.7	10.45	515.96	23.01	4.37	2018.39	34.12	23.01	
0.06101	0.7	10.69	518.82	23.92	4.44	2020.51	33.57	23.92	
0.06201	0.7	10.93	521.74	23.67	4.51	2022.78	33.05	23.67	
0.06301	0.7	11.18	524.79	24.05	4.58	2025.09	32.55	24.05	
0.06401	0.7	11.45	527.91	23.97	4.65	2027.51	32.08	23.97	
0.06501	0.7	11.74	531.19	24.53	4.72	2029.99	31.62	24.53	
0.06601	0.7	12.04	534.55	24.58	4.79	2032.59	31.18	24.58	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.06701	0.7	12.35	538.02	24.70	4.85	2035.26	30.76	24.70	
0.06801	0.7	12.68	541.54	24.53	4.91	2038.01	30.37	24.53	
0.02901	0.807	8.14	485.53	29.55	3.15	2165.34	72.38	29.55	114.03
0.03001	0.807	8.29	487.74	29.84	3.28	2166.90	69.55	29.84	
0.03101	0.807	8.46	490.11	29.92	3.40	2168.60	66.98	29.92	
0.03201	0.807	8.63	492.67	30.06	3.53	2170.44	64.63	30.06	
0.03301	0.807	8.83	495.44	30.59	3.65	2172.42	62.46	30.59	
0.03401	0.807	9.04	498.38	30.43	3.77	2174.56	60.48	30.43	
0.03501	0.807	9.28	501.58	31.32	3.89	2176.84	58.63	31.32	
0.03601	0.807	9.54	505.05	32.06	4.01	2179.32	56.89	32.06	
0.03701	0.807	9.82	508.70	32.04	4.12	2182.00	55.29	32.04	
0.03801	0.807	10.12	512.53	31.93	4.24	2184.83	53.84	31.93	
0.03901	0.807	10.45	516.60	32.36	4.35	2187.80	52.48	32.36	
0.04001	0.807	10.80	520.87	32.52	4.45	2190.95	51.23	32.52	
0.04101	0.807	11.19	525.43	33.28	4.56	2194.27	50.04	33.28	
0.04201	0.807	11.60	530.22	33.53	4.66	2197.81	48.95	33.53	
0.04301	0.807	12.06	535.30	34.32	4.76	2201.53	47.91	34.32	
0.04401	0.807	12.55	540.56	34.20	4.86	2205.48	46.95	34.20	
0.02301	0.905	8.16	485.95	35.78	3.17	2297.37	92.15	35.78	146.16
0.02401	0.905	8.36	488.89	36.00	3.34	2299.42	87.58	36.00	
0.02501	0.905	8.58	492.12	36.20	3.50	2301.69	83.55	36.20	
0.02601	0.905	8.84	495.77	37.54	3.66	2304.21	79.85	37.54	
0.02701	0.905	9.13	499.64	36.83	3.81	2307.02	76.64	36.83	
0.02801	0.905	9.46	504.02	38.65	3.97	2310.03	73.63	38.65	
0.02901	0.905	9.82	508.72	38.74	4.12	2313.41	70.96	38.74	
0.03001	0.905	10.22	513.70	38.46	4.26	2317.03	68.58	38.46	
0.03101	0.905	10.67	519.12	39.57	4.40	2320.88	66.39	39.57	
0.03201	0.905	11.16	524.96	40.21	4.54	2325.07	64.39	40.21	
0.03301	0.905	11.71	531.15	40.56	4.67	2329.57	62.58	40.56	
0.03401	0.905	12.33	537.84	41.78	4.80	2334.36	60.91	41.78	
0.03501	0.905	13.01	544.87	41.97	4.92	2339.51	59.39	41.97	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02001	1.011	8.22	487.28	39.97	3.11	2387.97	119.52	39.97	186.10
0.02101	1.011	8.45	490.59	39.65	3.31	2390.33	112.55	39.65	
0.02201	1.011	8.72	494.42	41.09	3.50	2392.99	106.34	41.09	
0.02301	1.011	9.04	498.72	41.85	3.69	2396.04	100.89	41.85	
0.02401	1.011	9.41	503.58	43.03	3.88	2399.46	96.04	43.03	
0.02501	1.011	9.86	509.32	46.50	4.07	2403.38	91.50	46.50	
0.02601	1.011	10.38	515.77	48.05	4.26	2407.93	87.44	48.05	
0.02701	1.011	11.01	523.13	50.81	4.44	2413.06	83.75	50.81	
0.02801	1.011	11.74	531.29	52.38	4.63	2418.87	80.46	52.38	
0.02901	1.011	12.59	540.24	53.84	4.80	2425.29	77.54	53.84	
0.03001	1.011	13.52	549.59	53.04	4.96	2432.22	75.04	53.04	
DATA SET – IV									
0.05501	0.701	10.69	494.85	19.84	3.67	2004.61	35.34	19.84	64.84
0.05601	0.701	10.84	496.58	19.95	3.74	2005.92	34.67	19.95	
0.05701	0.701	11.00	498.44	20.61	3.81	2007.29	34.00	20.61	
0.05801	0.701	11.17	500.32	20.12	3.88	2008.75	33.39	20.12	
0.05901	0.701	11.34	502.29	20.49	3.95	2010.23	32.80	20.49	
0.06001	0.701	11.53	504.36	20.78	4.02	2011.79	32.22	20.78	
0.06101	0.701	11.72	506.43	20.07	4.09	2013.43	31.70	20.07	
0.06201	0.701	11.92	508.60	20.43	4.16	2015.06	31.19	20.43	
0.06301	0.701	12.13	510.86	20.76	4.22	2016.78	30.70	20.76	
0.06401	0.701	12.35	513.16	20.40	4.29	2018.57	30.24	20.40	
0.06501	0.701	12.59	515.63	21.45	4.35	2020.38	29.78	21.45	
0.06601	0.701	12.83	518.13	21.03	4.42	2022.35	29.35	21.03	
0.06701	0.701	13.08	520.69	20.97	4.48	2024.32	28.94	20.97	
0.06801	0.701	13.36	523.38	21.55	4.54	2026.35	28.54	21.55	
0.06901	0.701	13.64	526.16	21.73	4.61	2028.48	28.15	21.73	
0.07001	0.701	13.94	529.00	21.65	4.67	2030.69	27.78	21.65	
0.07101	0.701	14.25	531.94	21.89	4.73	2032.95	27.43	21.89	
0.07201	0.701	14.57	534.90	21.56	4.79	2035.28	27.10	21.56	
0.07301	0.701	14.91	537.99	22.03	4.84	2037.63	26.77	22.03	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.07401	0.701	15.27	541.20	22.43	4.90	2040.09	26.46	22.43	
0.03801	0.795	11.73	494.14	27.25	3.63	2155.33	57.73	27.25	104.64
0.03901	0.795	11.98	496.76	28.00	3.74	2157.19	56.03	28.00	
0.04001	0.795	12.25	499.48	27.79	3.84	2159.22	54.47	27.79	
0.04101	0.795	12.56	502.71	30.81	3.96	2161.35	52.89	30.81	
0.04201	0.795	12.89	505.95	29.42	4.06	2163.85	51.50	29.42	
0.04301	0.795	13.26	509.52	30.76	4.17	2166.37	50.16	30.76	
0.04401	0.795	13.66	513.35	31.57	4.28	2169.15	48.90	31.57	
0.04501	0.795	14.09	517.31	31.20	4.38	2172.13	47.74	31.20	
0.04601	0.795	14.56	521.60	32.30	4.49	2175.22	46.64	32.30	
0.04701	0.795	15.03	525.75	30.18	4.58	2178.54	45.69	30.18	
0.04801	0.795	15.56	530.31	31.86	4.68	2181.79	44.75	31.86	
0.04901	0.795	16.12	534.96	31.53	4.77	2185.33	43.89	31.53	
0.02401	0.902	10.02	485.96	33.70	3.14	2297.02	87.69	33.70	137.49
0.02501	0.902	10.24	488.64	33.77	3.29	2298.91	83.55	33.77	
0.02601	0.902	10.50	491.62	34.33	3.44	2300.99	79.82	34.33	
0.02701	0.902	10.77	494.79	33.77	3.59	2303.28	76.55	33.77	
0.02801	0.902	11.09	498.35	35.22	3.74	2305.74	73.51	35.22	
0.02901	0.902	11.45	502.22	35.55	3.89	2308.50	70.76	35.55	
0.03001	0.902	11.83	506.32	35.24	4.02	2311.49	68.32	35.24	
0.03101	0.902	12.27	510.83	36.42	4.16	2314.66	66.05	36.42	
0.03201	0.902	12.75	515.65	36.69	4.30	2318.15	63.98	36.69	
0.03301	0.902	13.27	520.80	37.13	4.43	2321.87	62.10	37.13	
0.03401	0.902	13.86	526.38	38.22	4.56	2325.85	60.35	38.22	
0.03501	0.902	14.51	532.29	38.51	4.68	2330.16	58.75	38.51	
0.03601	0.902	15.24	538.63	39.55	4.80	2334.73	57.27	39.55	
0.03701	0.902	16.08	545.70	42.18	4.92	2339.67	55.84	42.18	
0.02201	1.007	10.19	492.21	37.98	3.33	2394.42	107.49	37.98	179.14
0.02301	1.007	10.51	495.92	39.39	3.52	2397.01	101.88	39.39	
0.02401	1.007	10.89	500.20	41.26	3.70	2399.97	96.78	41.26	
0.02501	1.007	11.36	505.35	45.19	3.90	2403.45	91.94	45.19	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02601	1.007	11.89	511.01	45.45	4.08	2407.51	87.74	45.45	
0.02701	1.007	12.52	517.45	47.66	4.27	2412.01	83.92	47.66	
0.02801	1.007	13.24	524.45	48.17	4.45	2417.07	80.57	48.17	
0.02901	1.007	14.06	532.07	48.97	4.62	2422.57	77.61	48.97	
0.03001	1.007	14.96	540.12	48.72	4.77	2428.50	75.04	48.72	
0.03101	1.007	16.00	548.85	49.98	4.93	2434.80	72.72	49.98	

Appendix B-7 - HRJ – JP-8 Flame Speed Data

DATA SET – I									
Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.04001	0.704	4.75	484.50	26.84	3.17	2018.54	59.96	26.84	95.00
0.04101	0.704	4.82	486.19	24.77	3.27	2019.87	58.15	24.77	
0.04201	0.704	4.89	488.00	25.32	3.37	2021.19	56.44	25.32	
0.04301	0.704	4.97	490.10	27.51	3.47	2022.62	54.72	27.51	
0.04401	0.704	5.06	492.30	27.22	3.57	2024.26	53.14	27.22	
0.04501	0.704	5.15	494.57	26.69	3.67	2025.98	51.72	26.69	
0.04601	0.704	5.26	497.13	28.68	3.78	2027.76	50.29	28.68	
0.04701	0.704	5.37	499.79	28.25	3.88	2029.77	48.99	28.25	
0.04801	0.704	5.49	502.51	27.58	3.97	2031.85	47.80	27.58	
0.04901	0.704	5.61	505.40	28.01	4.07	2033.99	46.69	28.01	
0.05001	0.704	5.75	508.50	28.77	4.16	2036.26	45.62	28.77	
0.05101	0.704	5.90	511.75	29.01	4.26	2038.69	44.61	29.01	
0.05201	0.704	6.05	515.06	28.41	4.35	2041.24	43.69	28.41	
0.05301	0.704	6.22	518.66	29.75	4.44	2043.85	42.80	29.75	
0.05401	0.704	6.40	522.33	29.20	4.53	2046.68	41.97	29.20	
0.05501	0.704	6.60	526.32	30.70	4.62	2049.57	41.16	30.70	
0.05601	0.704	6.81	530.49	31.03	4.70	2052.71	40.40	31.03	
0.05701	0.704	7.03	534.75	30.75	4.79	2056.00	39.69	30.75	
0.05801	0.704	7.26	539.14	30.70	4.87	2059.37	39.03	30.70	
0.02501	0.802	4.71	483.47	34.87	3.09	2173.18	89.39	34.87	138.13
0.02601	0.802	4.81	486.04	35.31	3.25	2174.96	85.13	35.31	
0.02701	0.802	4.92	488.69	33.54	3.39	2176.93	81.53	33.54	
0.02801	0.802	5.05	491.81	36.21	3.54	2178.99	78.06	36.21	
0.02901	0.802	5.19	495.29	37.45	3.69	2181.39	74.86	37.45	
0.03001	0.802	5.35	499.01	37.19	3.84	2184.07	72.02	37.19	
0.03101	0.802	5.52	502.98	36.98	3.98	2186.93	69.49	36.98	
0.03201	0.802	5.72	507.41	38.80	4.12	2190.00	67.10	38.80	
0.03301	0.802	5.93	512.07	38.42	4.25	2193.41	64.96	38.42	
0.03401	0.802	6.16	516.94	37.96	4.38	2196.99	63.06	37.96	
0.03501	0.802	6.43	522.45	40.78	4.51	2200.77	61.21	40.78	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03601	0.802	6.73	528.27	40.95	4.64	2205.02	59.54	40.95	
0.03701	0.802	7.05	534.36	40.94	4.76	2209.51	58.02	40.94	
0.03801	0.802	7.39	540.77	41.22	4.88	2214.22	56.63	41.22	
0.02001	0.901	4.71	483.82	39.02	3.09	2304.78	113.67	39.02	175.86
0.02101	0.901	4.85	487.21	42.35	3.29	2306.96	106.80	42.35	
0.02201	0.901	5.00	490.97	42.24	3.48	2309.57	100.93	42.24	
0.02301	0.901	5.18	495.31	44.10	3.68	2312.50	95.65	44.10	
0.02401	0.901	5.39	500.12	44.48	3.86	2315.85	91.05	44.48	
0.02501	0.901	5.62	505.27	43.81	4.04	2319.54	87.10	43.81	
0.02601	0.901	5.88	511.09	45.82	4.21	2323.53	83.49	45.82	
0.02701	0.901	6.18	517.37	46.01	4.38	2328.00	80.31	46.01	
0.02801	0.901	6.53	524.30	47.62	4.54	2332.84	77.42	47.62	
0.02901	0.901	6.93	531.92	49.17	4.70	2338.19	74.80	49.17	
0.03001	0.901	7.36	539.89	48.70	4.85	2344.00	72.52	48.70	
0.01801	1.001	4.77	483.73	45.06	3.08	2390.51	129.28	45.06	198.98
0.01901	1.001	4.92	487.24	42.27	3.29	2393.08	121.06	42.27	
0.02001	1.001	5.11	491.77	47.99	3.52	2396.00	113.18	47.99	
0.02101	1.001	5.32	496.74	47.12	3.73	2399.56	106.69	47.12	
0.02201	1.001	5.57	502.23	47.09	3.93	2403.47	101.17	47.09	
0.02301	1.001	5.86	508.49	48.96	4.13	2407.84	96.25	48.96	
0.02401	1.001	6.19	515.29	48.95	4.32	2412.73	92.04	48.95	
0.02501	1.001	6.58	522.97	51.26	4.51	2418.10	88.23	51.26	
0.02601	1.001	7.03	531.46	52.83	4.69	2424.13	84.84	52.83	
0.02701	1.001	7.56	540.73	54.12	4.86	2430.75	81.85	54.12	
DATA SET – II									
0.04101	0.7	6.44	483.18	21.10	3.10	2011.86	53.63	21.10	83.10
0.04201	0.7	6.52	484.71	23.57	3.19	2012.87	52.05	23.57	
0.04301	0.7	6.61	486.34	23.93	3.29	2014.07	50.56	23.93	
0.04401	0.7	6.70	488.02	23.27	3.38	2015.35	49.20	23.27	
0.04501	0.7	6.80	489.84	23.98	3.47	2016.67	47.90	23.98	
0.04601	0.7	6.91	491.78	24.26	3.56	2018.09	46.67	24.26	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.04701	0.7	7.01	493.72	23.29	3.65	2019.61	45.57	23.29	
0.04801	0.7	7.13	495.79	23.68	3.73	2021.14	44.52	23.68	
0.04901	0.7	7.26	498.09	25.18	3.82	2022.77	43.47	25.18	
0.05001	0.7	7.40	500.42	24.49	3.91	2024.57	42.51	24.49	
0.05101	0.7	7.54	502.81	24.02	3.99	2026.41	41.63	24.02	
0.05201	0.7	7.69	505.41	25.20	4.08	2028.28	40.76	25.20	
0.05301	0.7	7.86	508.09	25.06	4.16	2030.33	39.95	25.06	
0.05401	0.7	8.03	510.88	25.17	4.24	2032.44	39.19	25.17	
0.05501	0.7	8.22	513.93	26.48	4.32	2034.65	38.43	26.48	
0.05601	0.7	8.42	516.99	25.70	4.40	2037.05	37.74	25.70	
0.05701	0.7	8.63	520.18	25.93	4.48	2039.46	37.08	25.93	
0.05801	0.7	8.84	523.43	25.63	4.56	2041.97	36.47	25.63	
0.05901	0.7	9.08	526.87	26.34	4.63	2044.54	35.87	26.34	
0.06001	0.7	9.33	530.45	26.63	4.71	2047.26	35.30	26.63	
0.06101	0.7	9.59	534.20	27.19	4.78	2050.09	34.76	27.19	
0.06201	0.7	9.87	538.03	26.99	4.85	2053.06	34.25	26.99	
0.06301	0.7	10.17	542.06	27.66	4.92	2056.09	33.75	27.66	
0.02801	0.806	6.53	484.15	31.86	3.14	2182.12	76.54	31.86	120.21
0.02901	0.806	6.65	486.44	30.79	3.27	2183.81	73.41	30.79	
0.03001	0.806	6.79	488.99	31.62	3.41	2185.58	70.51	31.62	
0.03101	0.806	6.95	491.81	32.54	3.54	2187.54	67.82	32.54	
0.03201	0.806	7.11	494.68	31.02	3.67	2189.70	65.51	31.02	
0.03301	0.806	7.30	497.93	32.87	3.80	2191.93	63.27	32.87	
0.03401	0.806	7.51	501.39	32.90	3.93	2194.44	61.24	32.90	
0.03501	0.806	7.73	505.02	32.53	4.05	2197.10	59.41	32.53	
0.03601	0.806	7.97	508.96	33.56	4.17	2199.90	57.69	33.56	
0.03701	0.806	8.25	513.30	35.01	4.29	2202.95	56.05	35.01	
0.03801	0.806	8.55	517.82	34.66	4.41	2206.30	54.57	34.66	
0.03901	0.806	8.86	522.51	34.37	4.52	2209.78	53.23	34.37	
0.04001	0.806	9.21	527.54	35.34	4.63	2213.41	51.96	35.34	
0.04101	0.806	9.59	532.80	35.48	4.73	2217.30	50.79	35.48	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.04201	0.806	10.00	538.34	35.96	4.84	2221.38	49.71	35.96	
0.04301	0.806	10.46	544.26	37.02	4.94	2225.68	48.68	37.02	
0.02201	0.898	6.53	484.11	36.56	3.12	2307.01	98.87	36.56	154.11
0.02301	0.898	6.70	487.15	37.96	3.29	2309.06	93.55	37.96	
0.02401	0.898	6.90	490.71	40.16	3.48	2311.43	88.66	40.16	
0.02501	0.898	7.10	494.34	37.40	3.64	2314.14	84.69	37.40	
0.02601	0.898	7.35	498.56	40.01	3.81	2316.97	80.94	40.01	
0.02701	0.898	7.63	503.05	39.40	3.97	2320.21	77.68	39.40	
0.02801	0.898	7.94	507.99	40.34	4.12	2323.67	74.72	40.34	
0.02901	0.898	8.29	513.42	41.45	4.28	2327.49	72.03	41.45	
0.03001	0.898	8.67	519.17	41.22	4.43	2331.65	69.64	41.22	
0.03101	0.898	9.10	525.37	41.96	4.57	2336.08	67.48	41.96	
0.03201	0.898	9.59	532.05	42.89	4.71	2340.85	65.50	42.89	
0.03301	0.898	10.12	539.10	43.12	4.84	2345.97	63.72	43.12	
0.03401	0.898	10.72	546.71	44.48	4.97	2351.41	62.07	44.48	
0.01901	0.985	6.42	483.09	39.33	3.04	2389.34	121.16	39.33	184.11
0.02001	0.985	6.60	486.51	42.11	3.25	2391.62	113.37	42.11	
0.02101	0.985	6.82	490.36	42.36	3.45	2394.33	106.72	42.36	
0.02201	0.985	7.06	494.53	41.27	3.64	2397.34	101.17	41.27	
0.02301	0.985	7.35	499.40	43.91	3.83	2400.67	96.07	43.91	
0.02401	0.985	7.67	504.69	43.62	4.02	2404.48	91.69	43.62	
0.02501	0.985	8.05	510.61	45.01	4.20	2408.65	87.76	45.01	
0.02601	0.985	8.49	517.28	47.02	4.37	2413.31	84.18	47.02	
0.02701	0.985	9.00	524.64	48.36	4.55	2418.54	80.98	48.36	
0.02801	0.985	9.61	532.93	51.08	4.72	2424.33	78.05	51.08	
0.02901	0.985	10.34	542.39	54.83	4.89	2430.88	75.31	54.83	

DATA SET – III									
Time [sec]	**Phi**	**Pressure [bar]**	**Temperature [°C]**	**Flame Speed [cm/sec]**	**Flame Radius [cm]**	**Flame Temperature [K]**	**Stretch Rate [1/s]**	**Flame Speed [cm/sec]**	**[dr/dt]**
0.04401	0.698	8.08	482.69	21.05	3.07	2008.59	48.78	21.05	74.99
0.04501	0.698	8.17	484.00	20.79	3.16	2009.58	47.49	20.79	
0.04601	0.698	8.26	485.42	21.36	3.24	2010.62	46.26	21.36	
0.04701	0.698	8.36	486.93	21.47	3.33	2011.73	45.09	21.47	
0.04801	0.698	8.46	488.44	20.67	3.41	2012.91	44.04	20.67	
0.04901	0.698	8.57	490.04	20.87	3.48	2014.10	43.04	20.87	
0.05001	0.698	8.70	491.82	22.29	3.57	2015.36	42.03	22.29	
0.05101	0.698	8.82	493.61	21.40	3.65	2016.76	41.12	21.40	
0.05201	0.698	8.96	495.48	21.51	3.73	2018.17	40.26	21.51	
0.05301	0.698	9.10	497.44	21.63	3.80	2019.64	39.44	21.63	
0.05401	0.698	9.25	499.51	22.05	3.88	2021.18	38.65	22.05	
0.05501	0.698	9.41	501.67	22.11	3.96	2022.81	37.91	22.11	
0.05601	0.698	9.58	503.94	22.46	4.03	2024.51	37.19	22.46	
0.05701	0.698	9.76	506.35	23.03	4.11	2026.30	36.49	23.03	
0.05801	0.698	9.95	508.79	22.61	4.18	2028.20	35.85	22.61	
0.05901	0.698	10.15	511.32	22.60	4.26	2030.13	35.24	22.60	
0.06001	0.698	10.36	513.97	22.99	4.33	2032.12	34.65	22.99	
0.06101	0.698	10.58	516.72	23.14	4.40	2034.21	34.09	23.14	
0.06201	0.698	10.81	519.55	23.17	4.47	2036.39	33.56	23.17	
0.06301	0.698	11.06	522.52	23.60	4.54	2038.63	33.04	23.60	
0.06401	0.698	11.32	525.56	23.47	4.61	2040.97	32.56	23.47	
0.06501	0.698	11.59	528.72	23.86	4.67	2043.37	32.09	23.86	
0.06601	0.698	11.88	532.01	24.17	4.74	2045.88	31.64	24.17	
0.06701	0.698	12.19	535.43	24.51	4.81	2048.49	31.20	24.51	
0.06801	0.698	12.51	538.90	24.29	4.87	2051.20	30.80	24.29	
0.02801	0.81	8.14	483.42	28.69	3.03	2189.40	74.77	28.69	113.29
0.02901	0.81	8.28	485.52	30.06	3.16	2190.83	71.63	30.06	
0.03001	0.81	8.43	487.74	29.41	3.29	2192.44	68.85	29.41	
0.03101	0.81	8.59	490.06	28.69	3.41	2194.15	66.39	28.69	
0.03201	0.81	8.78	492.64	29.76	3.54	2195.94	64.07	29.76	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03301	0.81	8.98	495.47	30.56	3.66	2197.94	61.90	30.56	
0.03401	0.81	9.19	498.40	29.82	3.78	2200.11	59.97	29.82	
0.03501	0.81	9.44	501.65	31.22	3.90	2202.38	58.12	31.22	
0.03601	0.81	9.70	505.14	31.59	4.02	2204.89	56.41	31.59	
0.03701	0.81	9.99	508.84	31.87	4.13	2207.58	54.82	31.87	
0.03801	0.81	10.29	512.61	30.88	4.24	2210.44	53.42	30.88	
0.03901	0.81	10.63	516.70	31.97	4.35	2213.35	52.08	31.97	
0.04001	0.81	10.99	520.99	32.08	4.46	2216.51	50.84	32.08	
0.04101	0.81	11.38	525.48	32.29	4.56	2219.83	49.69	32.29	
0.04201	0.81	11.81	530.30	33.25	4.66	2223.32	48.60	33.25	
0.04301	0.81	12.27	535.42	33.99	4.76	2227.05	47.57	33.99	
0.04401	0.81	12.77	540.66	33.54	4.86	2231.02	46.63	33.54	
0.04501	0.81	13.30	546.15	34.05	4.95	2235.08	45.75	34.05	
0.02301	0.902	8.27	485.97	36.51	3.16	2316.65	92.38	36.51	145.91
0.02401	0.902	8.47	488.94	36.28	3.33	2318.74	87.71	36.28	
0.02501	0.902	8.70	492.15	35.76	3.49	2321.02	83.67	35.76	
0.02601	0.902	8.96	495.74	36.74	3.65	2323.51	79.99	36.74	
0.02701	0.902	9.25	499.61	36.59	3.80	2326.27	76.75	36.59	
0.02801	0.902	9.58	503.95	38.11	3.96	2329.27	73.75	38.11	
0.02901	0.902	9.94	508.57	37.92	4.11	2332.61	71.08	37.92	
0.03001	0.902	10.34	513.55	38.26	4.25	2336.17	68.68	38.26	
0.03101	0.902	10.79	518.89	38.78	4.39	2340.00	66.50	38.78	
0.03201	0.902	11.29	524.68	39.69	4.52	2344.12	64.49	39.69	
0.03301	0.902	11.84	530.85	40.21	4.66	2348.58	62.67	40.21	
0.03401	0.902	12.47	537.52	41.44	4.79	2353.34	60.98	41.44	
0.03501	0.902	13.14	544.49	41.36	4.91	2358.47	59.46	41.36	
0.02001	1.006	8.27	485.95	39.83	3.14	2409.14	117.40	39.83	184.14
0.02101	1.006	8.51	489.36	39.73	3.33	2411.55	110.53	39.73	
0.02201	1.006	8.80	493.33	41.46	3.53	2414.29	104.39	41.46	
0.02301	1.006	9.12	497.63	40.76	3.71	2417.41	99.18	40.76	
0.02401	1.006	9.50	502.60	42.96	3.90	2420.85	94.42	42.96	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.02501	1.006	9.95	508.34	45.43	4.09	2424.82	90.06	45.43	
0.02601	1.006	10.48	514.77	46.93	4.27	2429.36	86.17	46.93	
0.02701	1.006	11.11	522.11	49.69	4.46	2434.47	82.60	49.69	
0.02801	1.006	11.85	530.28	51.53	4.64	2440.26	79.40	51.53	
0.02901	1.006	12.69	539.10	52.14	4.81	2446.63	76.60	52.14	
0.03001	1.006	13.65	548.55	52.80	4.97	2453.50	74.13	52.80	
DATA SET – IV									
0.04601	0.704	9.80	482.81	20.58	3.06	2019.36	45.43	20.58	69.45
0.04701	0.704	9.89	483.98	18.65	3.13	2020.32	44.34	18.65	
0.04801	0.704	9.99	485.24	19.14	3.21	2021.24	43.29	19.14	
0.04901	0.704	10.10	486.60	19.83	3.29	2022.23	42.26	19.83	
0.05001	0.704	10.22	487.97	19.08	3.36	2023.30	41.33	19.08	
0.05101	0.704	10.34	489.48	20.04	3.44	2024.37	40.41	20.04	
0.05201	0.704	10.47	491.03	19.92	3.51	2025.55	39.54	19.92	
0.05301	0.704	10.61	492.65	19.86	3.59	2026.78	38.72	19.86	
0.05401	0.704	10.76	494.38	20.38	3.66	2028.05	37.92	20.38	
0.05501	0.704	10.91	496.15	20.17	3.74	2029.41	37.18	20.17	
0.05601	0.704	11.07	498.00	20.19	3.81	2030.80	36.47	20.19	
0.05701	0.704	11.25	499.98	20.92	3.88	2032.25	35.78	20.92	
0.05801	0.704	11.43	502.02	20.88	3.95	2033.81	35.12	20.88	
0.05901	0.704	11.62	504.06	20.15	4.02	2035.42	34.52	20.15	
0.06001	0.704	11.81	506.21	20.56	4.09	2037.03	33.94	20.56	
0.06101	0.704	12.02	508.47	20.88	4.16	2038.72	33.38	20.88	
0.06201	0.704	12.25	510.82	21.17	4.23	2040.50	32.84	21.17	
0.06301	0.704	12.48	513.24	21.16	4.30	2042.36	32.32	21.16	
0.06401	0.704	12.72	515.74	21.17	4.36	2044.27	31.83	21.17	
0.06501	0.704	12.98	518.35	21.58	4.43	2046.24	31.36	21.58	
0.06601	0.704	13.25	521.03	21.55	4.49	2048.30	30.91	21.55	
0.06701	0.704	13.54	523.85	22.06	4.56	2050.42	30.47	22.06	
0.06801	0.704	13.84	526.71	21.90	4.62	2052.64	30.05	21.90	
0.06901	0.704	14.15	529.67	22.08	4.68	2054.91	29.65	22.08	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.07001	0.704	14.48	532.71	22.09	4.75	2057.26	29.27	22.09	
0.07101	0.704	14.82	535.84	22.31	4.81	2059.66	28.90	22.31	
0.07201	0.704	15.18	539.07	22.55	4.86	2062.14	28.55	22.55	
0.07301	0.704	15.56	542.42	22.84	4.92	2064.71	28.21	22.84	
0.03001	0.809	9.90	484.74	27.48	3.09	2190.14	67.76	27.48	104.79
0.03101	0.809	10.06	486.68	26.85	3.21	2191.55	65.28	26.85	
0.03201	0.809	10.23	488.78	27.30	3.33	2193.05	62.98	27.30	
0.03301	0.809	10.43	491.10	28.08	3.45	2194.67	60.81	28.08	
0.03401	0.809	10.63	493.44	26.75	3.56	2196.45	58.93	26.75	
0.03501	0.809	10.86	496.09	28.50	3.67	2198.27	57.08	28.50	
0.03601	0.809	11.11	498.98	29.22	3.79	2200.32	55.35	29.22	
0.03701	0.809	11.39	502.01	29.10	3.90	2202.55	53.76	29.10	
0.03801	0.809	11.68	505.16	28.71	4.01	2204.89	52.32	28.71	
0.03901	0.809	11.98	508.44	28.50	4.11	2207.32	51.00	28.50	
0.04001	0.809	12.33	512.03	29.76	4.22	2209.87	49.72	29.76	
0.04101	0.809	12.70	515.79	29.77	4.32	2212.64	48.54	29.77	
0.04201	0.809	13.09	519.70	29.74	4.42	2215.55	47.45	29.74	
0.04301	0.809	13.53	523.93	30.90	4.52	2218.58	46.40	30.90	
0.04401	0.809	13.99	528.31	30.76	4.61	2221.86	45.43	30.76	
0.04501	0.809	14.47	532.78	30.31	4.70	2225.25	44.55	30.31	
0.04601	0.809	15.00	537.53	31.11	4.80	2228.73	43.70	31.11	
0.04701	0.809	15.58	542.50	31.56	4.88	2232.41	42.91	31.56	
0.04801	0.809	16.20	547.76	32.38	4.97	2236.28	42.15	32.38	
0.02301	0.906	9.83	484.35	33.14	3.02	2323.38	91.82	33.14	138.82
0.02401	0.906	10.03	486.81	32.72	3.18	2325.12	87.34	32.72	
0.02501	0.906	10.27	489.63	34.04	3.34	2327.04	83.22	34.04	
0.02601	0.906	10.53	492.65	33.55	3.49	2329.21	79.62	33.55	
0.02701	0.906	10.82	496.00	34.41	3.64	2331.55	76.33	34.41	
0.02801	0.906	11.15	499.69	35.00	3.79	2334.15	73.34	35.00	
0.02901	0.906	11.51	503.65	35.14	3.93	2336.99	70.66	35.14	
0.03001	0.906	11.92	507.93	35.50	4.07	2340.04	68.23	35.50	

Time [sec]	Phi	Pressure [bar]	Temperature [°C]	Flame Speed [cm/sec]	Flame Radius [cm]	Flame Temperature [K]	Stretch Rate [1/s]	Flame Speed [cm/sec]	[dr/dt]
0.03101	0.906	12.37	512.57	36.19	4.21	2343.35	66.00	36.19	
0.03201	0.906	12.86	517.50	36.36	4.34	2346.92	63.98	36.36	
0.03301	0.906	13.41	522.86	37.39	4.47	2350.73	62.10	37.39	
0.03401	0.906	14.02	528.54	37.73	4.60	2354.85	60.39	37.73	
0.03501	0.906	14.70	534.65	38.68	4.72	2359.24	58.81	38.68	
0.03601	0.906	15.47	541.38	40.71	4.84	2363.98	57.31	40.71	
0.03701	0.906	16.37	548.87	43.43	4.97	2369.21	55.86	43.43	
0.02101	1.013	10.02	486.96	36.77	3.17	2417.61	114.97	36.77	182.30
0.02201	1.013	10.31	490.32	38.43	3.36	2419.93	108.55	38.43	
0.02301	1.013	10.64	494.14	39.38	3.54	2422.61	102.86	39.38	
0.02401	1.013	11.05	498.76	43.04	3.74	2425.71	97.49	43.04	
0.02501	1.013	11.56	504.16	45.76	3.94	2429.42	92.57	45.76	
0.02601	1.013	12.13	510.13	46.23	4.13	2433.68	88.30	46.23	
0.02701	1.013	12.80	516.77	47.56	4.31	2438.40	84.50	47.56	
0.02801	1.013	13.56	524.08	48.56	4.49	2443.63	81.14	48.56	
0.02901	1.013	14.41	531.82	48.15	4.66	2449.32	78.24	48.15	
0.03001	1.013	15.38	540.13	48.71	4.82	2455.36	75.68	48.71	
0.03101	1.013	16.47	549.07	49.70	4.97	2461.85	73.38	49.70	

APPENDIX C

R8 ROTARY FUEL INJECTION PUMP WEAR TESTING

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Approved for public release, distribution unlimited.

November 2012

C1.0 EXECUTIVE SUMMARY

Initial tests with R8 HRJ fuels revealed severe wear and extreme life reduction of rotary fuel injection pumps for diesel engines. The untreated R8 HRJ fuel caused performance degrading wear on rotary fuel injection pumps within 25-hours of operation on the untreated fuel. Previous work with low lubricity synthetic kerosene fuels showed those fuels responded well to the addition of a Corrosion Inhibitor/Lubricity Improver (CI/LI) additive to extend the life of the rotary fuel injection equipment.

The impact of minimal QPL-25017 CI/LI additive levels on fuel injection pump durability with R8 fuel was investigated. The minimal additive levels were determined by the additive concentration that resulted in an ASTM D5001 BOCLE wear scar targets of 0.75-mm and 0.85-mm. The resulting test fuels were R8 + 8.5-ppm DCI-4A with a 0.75-mm BOCLE wear scar, and R8 + 2.75-ppm DCI-4A with a 0.83-mm BOCLE wear scar.

Although the 0.75-mm BOCLE wear scar R8 fuel completed 500-hours of operation there was performance degradation of the fuel injection pumps, such that engine peak torque would be decreased, the engine peak power would be decreased, and with the cranking speed delivery at zero, an engine would be unable to start with these pumps. This additive treatment level R8 fuel would not be recommended for diesel engine use.

The 0.83-mm BOCLE wear scar R8 fuel completed only 183-hours of operation due to substantial over fuelling by the fuel injection pumps, such that exhaust black smoke would increase at all conditions, the cranking speed delivery increase would cause white smoke, possibly too rich to ignite, and half of the fuel injectors exhibited performance degradation that would impact engine operation and emissions. This additive treatment level for R8 fuel is ineffectual in providing proper diesel engine rotary fuel injection pump wear protection

C2.0 BACKGROUND AND OBJECTIVE

Initial tests with R8 HRJ fuels revealed severe wear and extreme life reduction of rotary fuel injection pumps for diesel engines. The untreated R8 HRJ fuel caused performance degrading wear on rotary fuel injection pumps within 25-hours of operation on the untreated fuel. However the wear seen with the untreated R8 HRJ fuel was not dissimilar to wear observed with untreated S8 or untreated S5 fuels in the same equipment. Previous work with S8/S5 fuels showed those fuels responded well to the addition of a Corrosion Inhibitor/Lubricity Improver (CI/LI) additive to extend the life of the rotary fuel injection equipment. In addition it is likely the R8 HRJ fuel will be used as a blending component with petroleum JP-8 fuel at a maximum 50-percent in order to maintain fuel density above the JP-8 specification minimum.

In conducting additive treated R8 fuel blend pump stand tests, it was found that the tests could be operated to conclusion at 500-hours:

- R8 fuel with 22.5-ppm DCI-4A CI/LI additive
- R8/Jet-A fuel blend with 22.5-ppm DCI-4A CI/LI additive
- Light component wear
- Substantial durability increase over neat R8 fuel

The most frequent out of specification parameters during the post-test pump and fuel injector performance checks for the additive treated R8 and R8/JP-8 blend were:

- Tip dryness, seat sealing, of fuel injectors with R8/Jet-A fuel blend
- Decreased fuel flow at Idle and Rated speeds
- R8 fuel with 22.5-ppm DCI-4A CI/LI additive was slightly more erratic in fuel delivery throughout the 500-hour test
- R8/Jet-A fuel blend with 22.5-ppm DCI-4A CI/LI additive had slightly less component wear, and slightly better 500-hour delivery performance.

The objective of the current study was to look at the effectiveness of a CI/LI additive at minimal treat rates, targeting ASTM D5001 Ball-On-Cylinder-Lubricity-Evaluator (BOCLE) Wear Scar Diameter (WSD) values, in extending rotary fuel injection equipment durability while operating on R8 HRJ fuel. The targeted WSD values for rotary pump testing with CI/LI additive treated R8 fuels testing were 0.85-mm and 0.75-mm.

C3.0 APPROACH

Endurance tests were performed using a motorized pump stand to define the effects of fuel and fuel additives on full-scale fuel injection equipment durability. The test series will attempt to determine the level of fuel injection system degradation due to wear and failure of the boundary film in R8 HRJ fuels with minimal additive treatments. A 500-hour pump operating procedure will be utilized.

C4.0 SCOPE OF WORK

C4.1 Fuels

Discussions on the task direction have indicated a desire to evaluate two intermediate values of R8 fuel lubricity as determined by ASTM D5001 BOCLE test. The target BOCLE values for R8 fuel testing are 0.75-mm and 0.85-mm wear scars for 500-hour test durations. Four drums of R8 test fuel were received at SwRI. Two drums of test fuel for each 500-hour test. Target test blends are being made to determine the additive levels required to meet the ASTM D5001 BOCLE target values.

An ASTM D5001 BOCLE sensitivity study was performed for the R8 test fuel, by evaluating 0, 5, 10, 15, and 20-ppm levels of DCI-4A into the test fuel, the results are shown in Figure C-1.

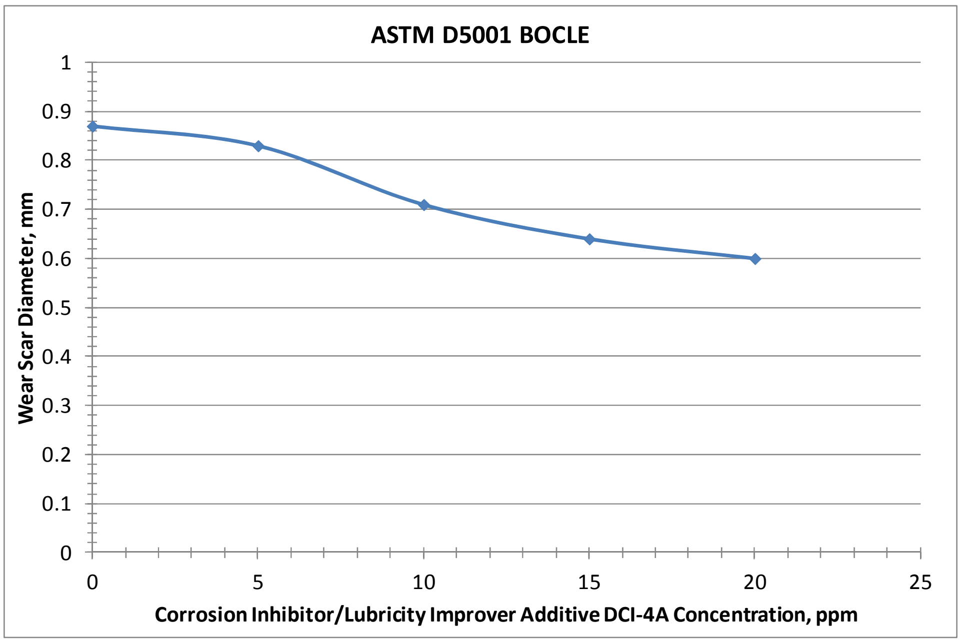


Figure C-1. ASTM D5001 Results for R8 Test Fuel and Additive Concentration

Based on the additive sensitivity of the R8 fuel shown in Figure C-1, the 0.85-mm wear scar will require around 3-ppm additive. The 0.75-mm wear scar fuel for the second test will require approximately 8.5-ppm additive. Pilot blends were made with 3-ppm and 8.5-ppm additive concentrations to confirm the sensitivity results. The 8.5-ppm additive pilot blend resulted in a 0.75-mm BOCLE wear scar, so two drums of test fuel will be blended at 8.5-ppm DCI-4A additive. The 3-ppm additive pilot blend resulted in a 0.79-mm BOCLE wear scar. The flatness of the additive sensitivity curve at low additive levels, and test repeatability, dictate additional pilot blends are made to hit the 0.85-mm BOCLE wear scar target. A blend with 2.75-ppm DCI-4A resulted in a BOCLE wear scar of 0.83-mm, which was the blend chosen for testing.

C4.2 Fuel Injection System Stanadyne

Rotary distributor fuel injection pumps are fuel lubricated, thus sensitive to fuel lubricity. Highly refined, low sulfur and low aromatic fuels can cause substantial performance degradation with

these pumps. Wear seen in the Stanadyne pumps could be interpolated to rotary distributor pumps of other manufacture.

C4.3 Pump Test Procedure

Full-scale equipment tests were performed using new injection pumps and fuel injectors with each test fuel. The pump tests were performed in duplicate in order to obtain average wear results. Two fifty-five gallon drums of the appropriate test fuel are normally required for each 500-hour pump tests. The 500-hour tests were performed under steady state conditions at maximum fuel delivery for the test pump, as summarized in Table C-1. The tests will be occasionally halted and restarted as necessary due to scheduling requirements or technical reasons. The pumps were started gradually to prevent seizure due to thermal shock. To further reduce the risk of seizure due to differential expansion, the fuel was not preheated prior to starting the pumps.

Table C-1. Pump Operating Conditions

Parameter:	Value:
Duration, hrs	500
Speed, RPM	1800
Fuel Inlet Temperature, °C	40
Throttle position	Full
Fuel-drum temperature, °C	<30

The test stand includes injection flow and pump return pipes, lift pumps, filters, flow meters, a fuel pre-heater and a heat exchanger to reduce the temperature of the fuel before returning to the storage tank. A schematic diagram of the fuel supply system proposed for the pump stand is shown in Figure C-2. The temperature of the incoming fuel to each pump will be controlled to 40°C.

The high-pressure outlets from the pumps will be connected to fuel injectors assembled in a collection canister.

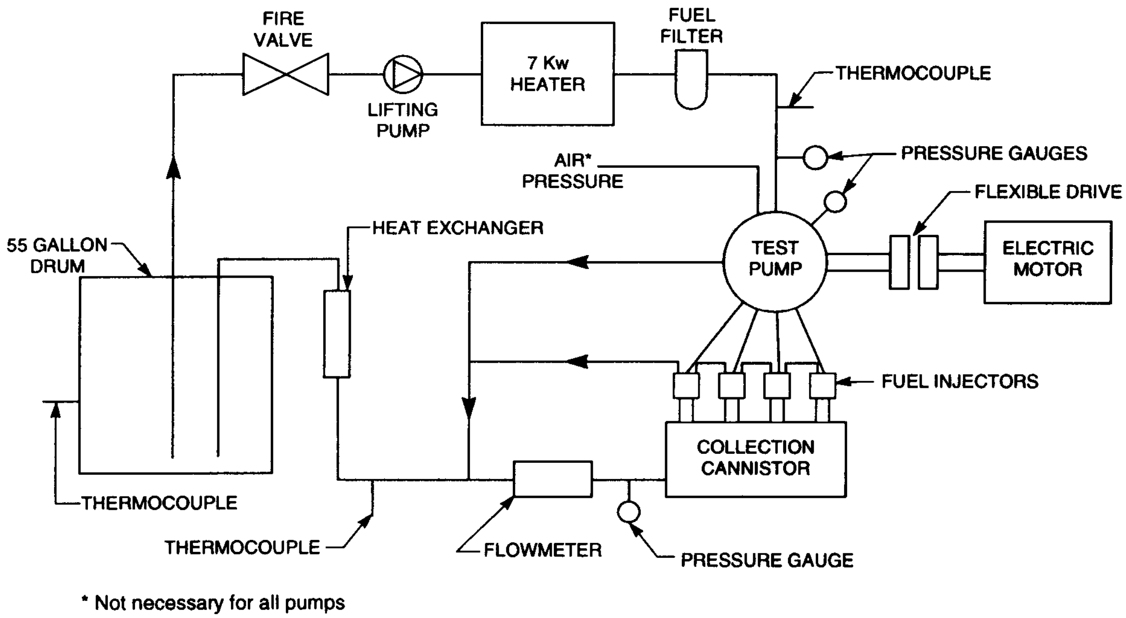


Figure C-2. Schematic Diagram of Fuel Delivery System

C4.4 Laboratory Scale Wear Tests

Stanadyne has indicated the lubricity of the test fuel should be determined prior to testing. Stanadyne has recommended the test fuel be changed at 250-hour intervals. The laboratory scale wear performed on the test fuels was the Ball on Cylinder Lubricity Evaluator procedure described in ASTM D5001, because that procedure is called out for aviation kerosene fuels and additives.

C4.5 Evaluation of the Pumps Using a Calibrated Test Stand

Prior to and following each 500-hour pump test, the performance of the Stanadyne pumps will be evaluated using a calibrated test stand. The objective of the calibration stand evaluation is to define the effect of the durability testing on pump performance. The calibration stand evaluations will be performed at an authorized pump distributor. No adjustments will be made to any of the pumps to achieve the manufacturer's specifications, either before, during, or following the 500-hour pump stand tests.

The appropriate inspection and test procedures for determining fuel injector performance will be followed prior to, and after each fuel evaluation.

C4.6 Pump Disassembly and Wear Evaluation

The pumps and fuel injectors will be disassembled at SwRI® following completion of the 500-hour durability test and the subsequent evaluation using the calibrated test stand. A SwRI disassembly and rating procedure was originally developed for the U.S. Army for use with Stanadyne equipment. Each sliding contact within the pump is rated on a scale from 0 to 5, with 0 corresponding to no wear and 5 corresponding to severe wear and failure. The wear scars on components throughout the pump are evaluated visually and quantitative measurements of wear volume will be made on critical pump components. The SwRI procedure looks at all wear contacts within the pump and injectors, which are lubricated by the fuel.

C5.0 PUMP TEST STAND EVALUATIONS

C5.1 Rotary Pump Test Procedure

The Stanadyne arctic pumps used for this program are opposed-piston, inlet-metered, positive-displacement, rotary-distributor, fuel-lubricated injection pumps, model DB2831-5209, for a General Engine Products 6.5L engine application. The arctic pump is equipped with hardened transfer pump blades, transfer pump liner, governor thrust washer, and drive shaft tang to reduce wear in these critical areas of the pump. A schematic diagram of the principal pump components is provided in Figure C-3.

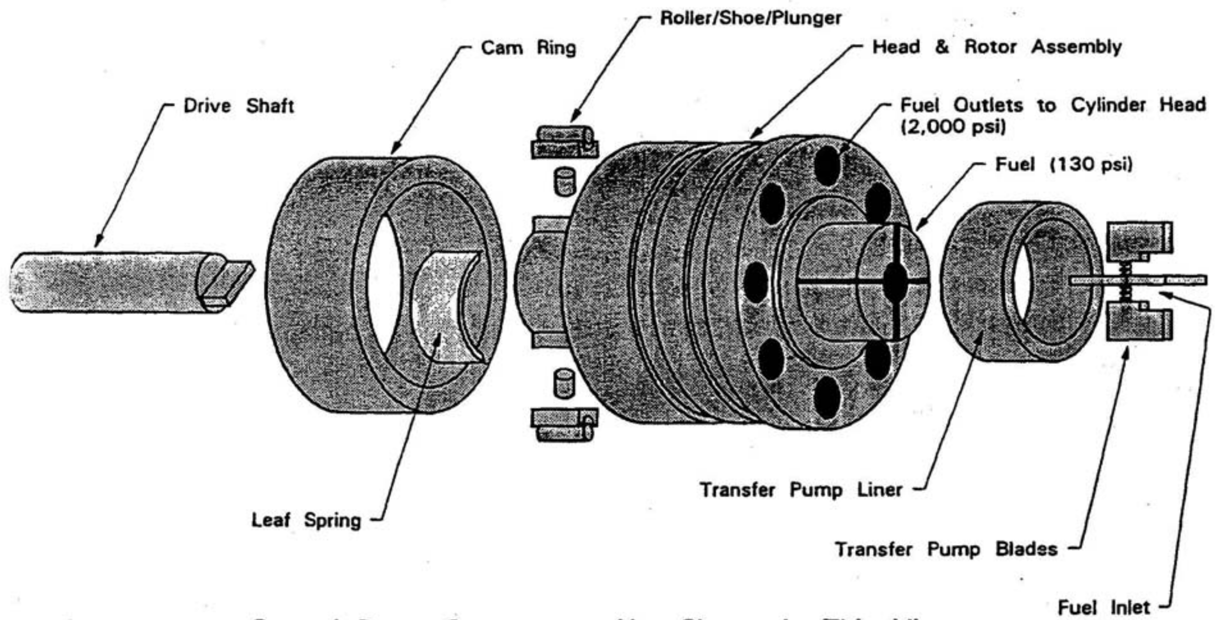


Figure C-3. Schematic Diagram of Principal Pump Components

The new pumps were disassembled, and pre-test roller-to-roller dimensions and transfer pump blade heights were obtained. Roller-to-roller dimensions were set per Stanadyne Diesel Systems Injection Pump Specifications for the DB2831-5209 model. The specification calls for a roller-to-roller dimension setting of 1.962 inches ± .001 inches. All pumps were set prior to testing with instructions that the roller-to-roller dimension not be adjusted during pre- and post-performance evaluations so that wear in these components could be accurately measured. Although there are not any min-max specifications other than initial assembly values, wear calculation from the roller-to-roller dimension is an excellent benchmark for the effects of fuel lubricity.

The pumps were reassembled and pre-test performance evaluations were conducted. The pumps were then mounted on the test stand and operated at 1800-RPM, with the fuel levers in the wide open throttle position (WOT) for targeted 500-hour increments (or less). Fuel flow, fuel inlet and outlet temperatures, transfer pump, pump housing pressures, and RPM were tracked and recorded. Flow meter readings reflect the injected fuel from the eight fuel injectors in each

collection canister. Any wear in the fuel injection pump metering section was reflected as an increased or reduced flow reading. The fuel inlet temperature control target was 40°C. Fuel inlet temperature variations directly can affect the fuel return temperature; the fuel return temperature is a function of accelerated pump wear. The transfer pump pressure is the regulated pressure the metal blade transfer pump supplies to the pump metering section. With low lubricity fuels, wear is likely to occur in the transfer pump blades, blade slot, and eccentric liner. Wear in these areas generally causes the transfer pump pressure to decrease. However, because the transfer pump has a pressure regulator, significant wear needs to occur in the transfer pump before the fuel pressure drops to below the operating range allowed in the pump specification. The housing pressure is the regulated pressure in the pump body that affects fuel metering and timing. With low lubricity fuel, wear occurs in high fuel pressure generating opposed plungers and bores, and between the hydraulic head and rotor. Leakage from the increased diametrical clearances of the plunger bores and the hydraulic head and rotor, results in increased housing pressures. Increased housing pressure reduces metered fuel and retards injection timing.

C5.2 Pump Test Stand

The rotary pumps were tested on a drive stand with a common fuel supply. To insure a realistic test environment, the mounting arrangement and drive gear duplicate that of the 6.5L engine. The fuel was maintained in a 55-gallon drum and continuously recirculated throughout the duration of each test. A gear pump provided a positive head of 3 psig at the inlet to the test pumps. A cartridge filter rated at 2 microns was used to remove wear debris and particulate contamination. Finally, a 5-kW Chromalox explosion-resistant circulation heater produced the required fuel inlet temperature.

The high-pressure outlets from the pumps were connected to eight Bosch Model O432217104 fuel injectors for a 6.5L engine and assembled in a collection canister. Fuel from both canisters was then returned to the 55-gallon drum. A separate line was used to return excess fuel from the governor housing to the fuel supply. Fuel-to-water heat exchangers on both the return lines from the injector canisters and the governor housing were used to cool the fuel. The test stand with pumps mounted is shown in Figure C-4.

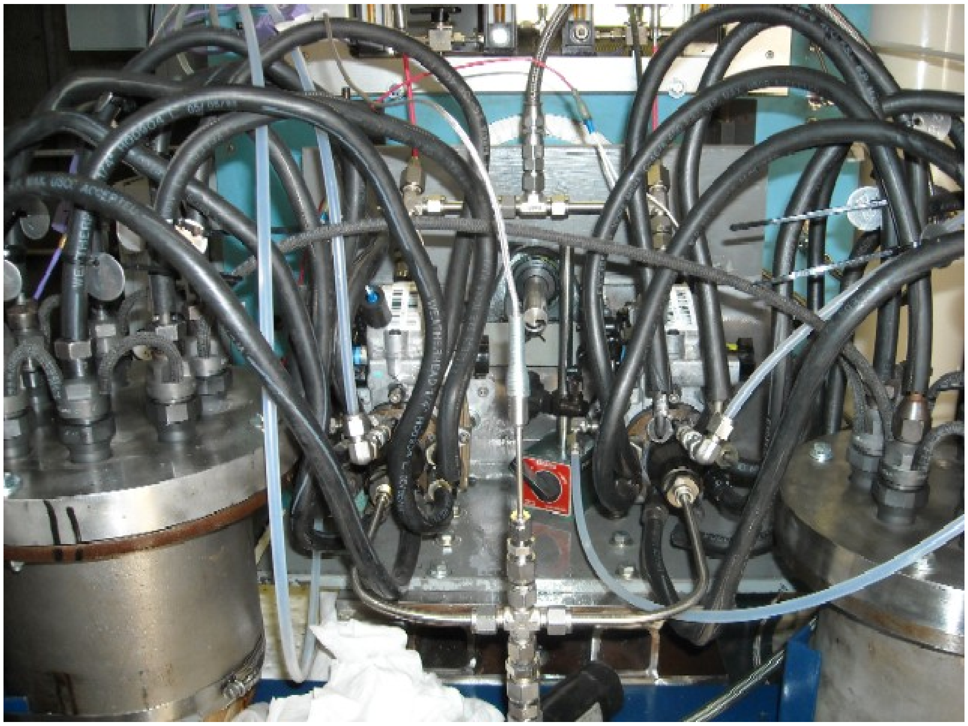


Figure C-4. Dual Stanadyne Rotary Fuel Injection Pumps Mounted on Stand with Fuel Injectors

A data acquisition and control system recorded pump stand RPM, fuel inlet pressure, fuel inlet and return temperature, transfer pump pressures, pump housing pressures, and fuel flow readings. The entire rig was equipped with safety shutdowns that would turn off the drive motor in the event of low fluid level in the supply drum, high inlet and return fuel temperature (70º C), or low or high transfer pump and housing pressure. Since high-return fuel temperature is a precursor of accelerated wear, this fail-safe feature reduces the possibility of head and rotor seizure.

C6.0 ROTARY FUEL INJECTION PUMP EVALUATIONS AND RESULTS

C6.1 Rotary Fuel Injection Pumps with CI/LI Additive Treated R8 Fuel

C6.1.1 R8 Fuel with 8.5-ppm DCI-4A CI/LI Additive

The Stanadyne model DB2831-5209 rotary fuel injection pumps were received from a supplier and the pumps appeared to be in good condition. The fuel injection pumps were installed on the test stand and the pumps were operated for an hour to validate their operation and to run-in the components with a good lubricity calibration fluid. The pumps were run for 30-minutes at 1200-RPM pump speed, with a half-rack fuel flow setting. For the final 30-minutes of the run-in the pumps were operated at the test condition of 1800-RPM pump speed, with a full-rack fuel flow setting.

The test bench and pumps were flushed with isooctane to attempt to remove any remaining run-in fluid. The isooctane was forced through the fuel injection pumps with pressure; the pumps were not run with isooctane in them. Following the isooctane flush, the treated R8 + 8.5-ppm DCI-4A was introduced into the test stand and the stand was operated at an idle condition until 2L of fuel was flushed through each set of eight injectors.

The testing with the treated R8+8.5-ppm DCI-4A fuel was initiated and the fuel injection pumps and stand control system appeared to function properly. The temperature and flow histories of the fuel injection pumps are shown in Figure C-5. The fuel return temperatures were consistent for pump SN: 15284298, which indicated there was not any unusual wear in the fuel injection pump. Pump SN: 15824300 revealed an increasing return fuel temperature from 100 to 250 hours (indicating a period of increased wear), after which time the return temperature decreased.

Both pumps completed 250-hours of operation with a decrease in delivery of around 7-percent. Fuel injection pump SN: 15824300 appeared to have a more erratic delivery. Both fuel injection pumps completed 500-hours operation; however the injected delivery for both pumps had decreased approximately 15-percent. Both fuel injection pumps had light brown staining, but were free from the heavy brown deposition that had previously been seen with the neat R8 fuel.

Fuel injection pump SN: 15824298 and SN: 15824300 revealed a steady decrease in fuel delivery with a slight increase in housing pressure. Shown in Figure C-6 are the pressure histories for the test with the R8 + 8.5-ppm DCI-4A fuel testing. Housing pressure usually increases in these pumps when an excessive amount of high-pressure fuel leaks past the pumping plungers, indicating an increase of the plunger-to-bore clearance. Both injection pumps revealed slightly erratic delivery characteristics. Erratic delivery in these pumps could be due to metering valve wear or governor linkage wear. The transfer pump pressure histories for both pumps indicate wear in the transfer pump and transfer pump regulator lead to some erratic pressure histories, with pump SN: 15284298 being more erratic. At 500-hours of testing the tops of both fuel injection pumps were removed for inspection, and the pump housings were free of wear debris. Both fuel injection pumps appeared to be functioning normally at 500-hours on the test stand.

C6.1.2 R8 Fuel with 2.75-ppm DCI-4A CI/LI Additive

Two Stanadyne model DB2831-5209 fuel injection pumps were installed on the test stand and the pumps were operated for an hour to validate their operation and to run-in the components with a good lubricity calibration fluid. The pumps were run for 30-minutes at 1200-RPM pump

speed, with a half-rack fuel flow setting. For the final 30-minutes of the run-in the pumps were operated at the test condition of 1800-RPM pump speed, with a full-rack fuel flow setting.

The test bench and pumps were flushed with isooctane to attempt to remove any remaining run-in fluid. The isooctane was forced through the fuel injection pumps with pressure; the pumps were not run with isooctane in them. Following the isooctane flush, the treated R8 + 2.75-ppm DCI-4A fuel was introduced into the test stand and the stand was operated at an idle condition until 2L of fuel was flushed through each set of eight injectors.

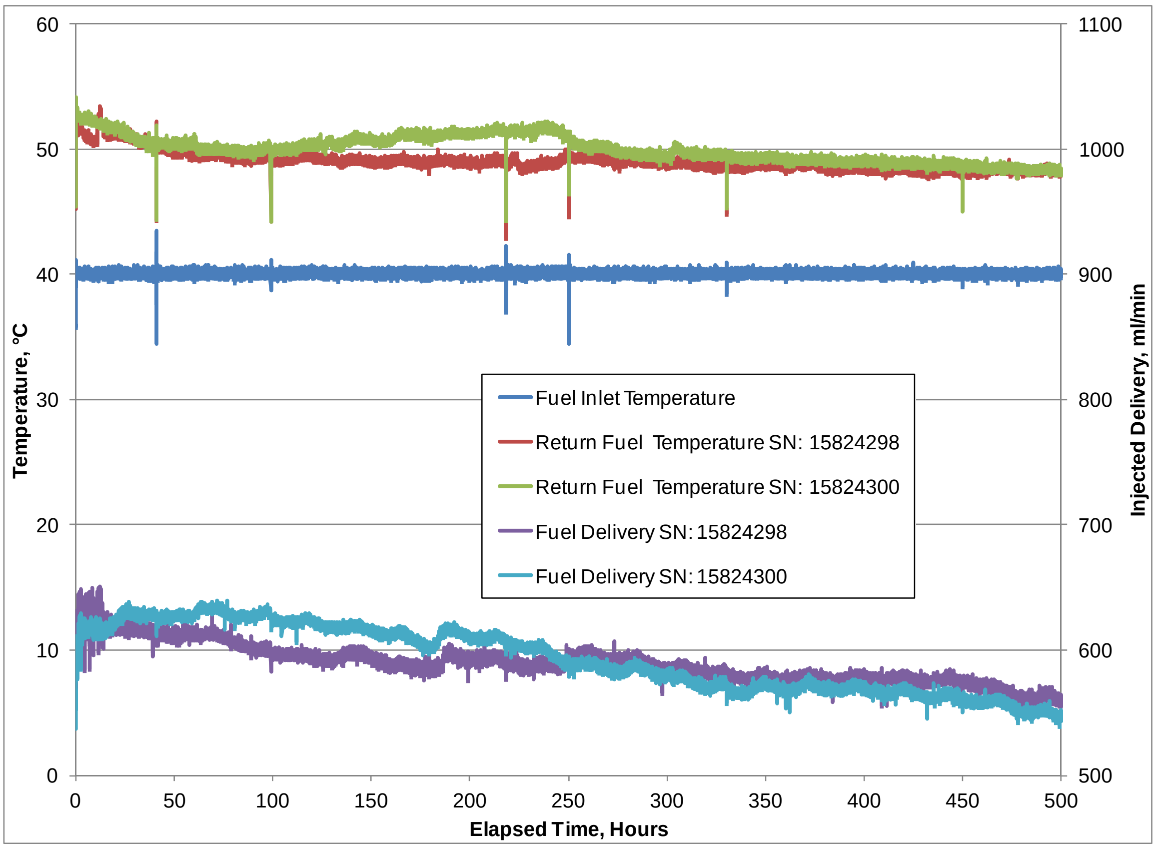


Figure C-5. Fuel Inlet, Fuel Return Temperatures and Fuel Flowrate Histories for R8+8.5-ppm DCI-4A Fuel

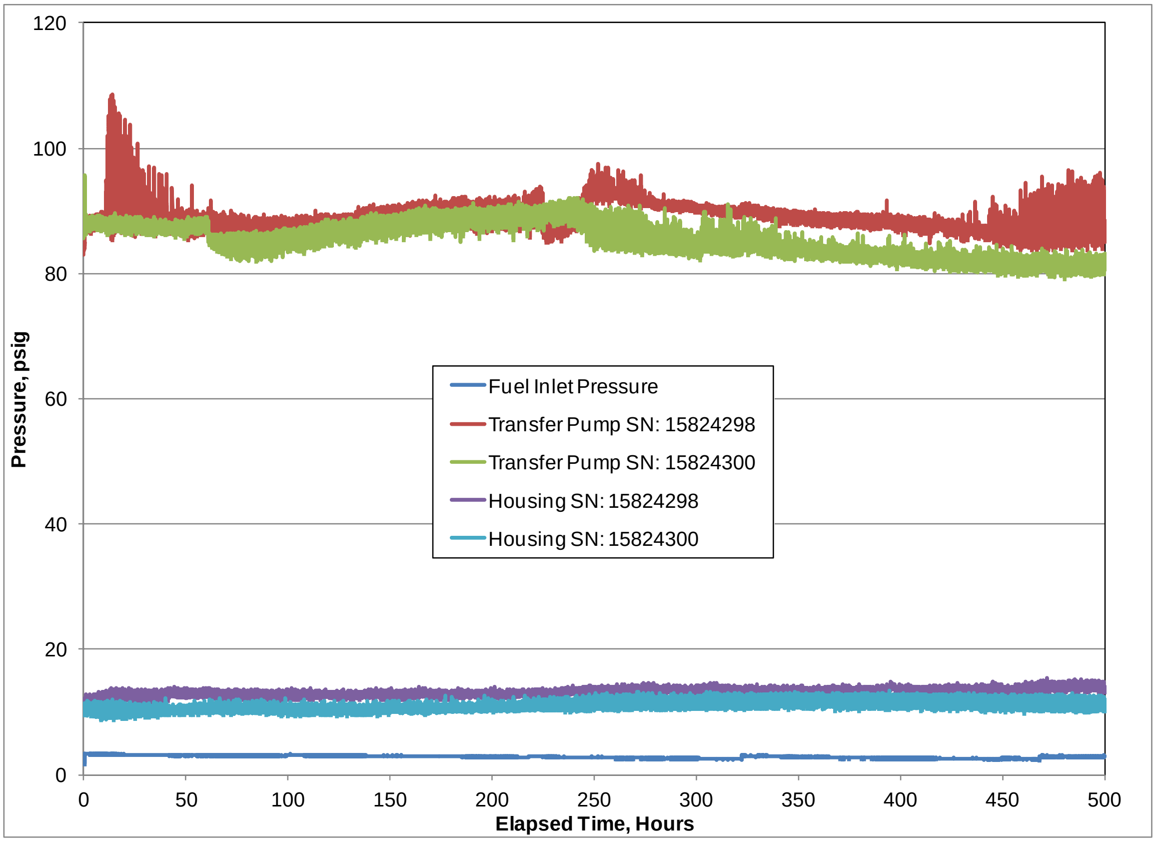


Figure C-6. Fuel Inlet, Fuel Transfer Pump, and Housing Pressure Histories for R8+8.5-ppm DCI-4A Fuel

The testing with the R8+2.75-ppm DCI-4A fuel was initiated and the fuel injection pumps and stand control system initially functioned normally. The temperature and flow histories of the fuel injection pumps are shown in Figure C-7. From the onset of testing both fuel injection pumps exhibited some form of erratic behavior. Pump SN: 15824304 rapidly increased injected delivery and the return fuel temperature increased, usually signs of leaf spring/roller shoe contact wear, and plunger /roller shoe contact wear. Pump SN: 15824313 exhibited steady initial delivery but a very erratic fuel return temperature, indicating increased internal friction. Around 75-hours of operation pump SN: 15824304 stabilized delivery at a 58-percent increased value. At the same interval pump SN: 15824313 started to rapidly increase delivery volumes and return fuel temperature, eventually exhibiting a 70-percent increased delivery. Unusual wear in the pumps usually causes an increase in the fuel return temperatures and delivery. Due to rapid delivery increases both fuel injection pumps operating on the R8 + 2.75-ppm DCI-4A fuel blend were terminated at 183-hours of operation. It should be noted the previous neat R8 test was also terminated due to increased fuel delivery, but at 25-hours of operation.

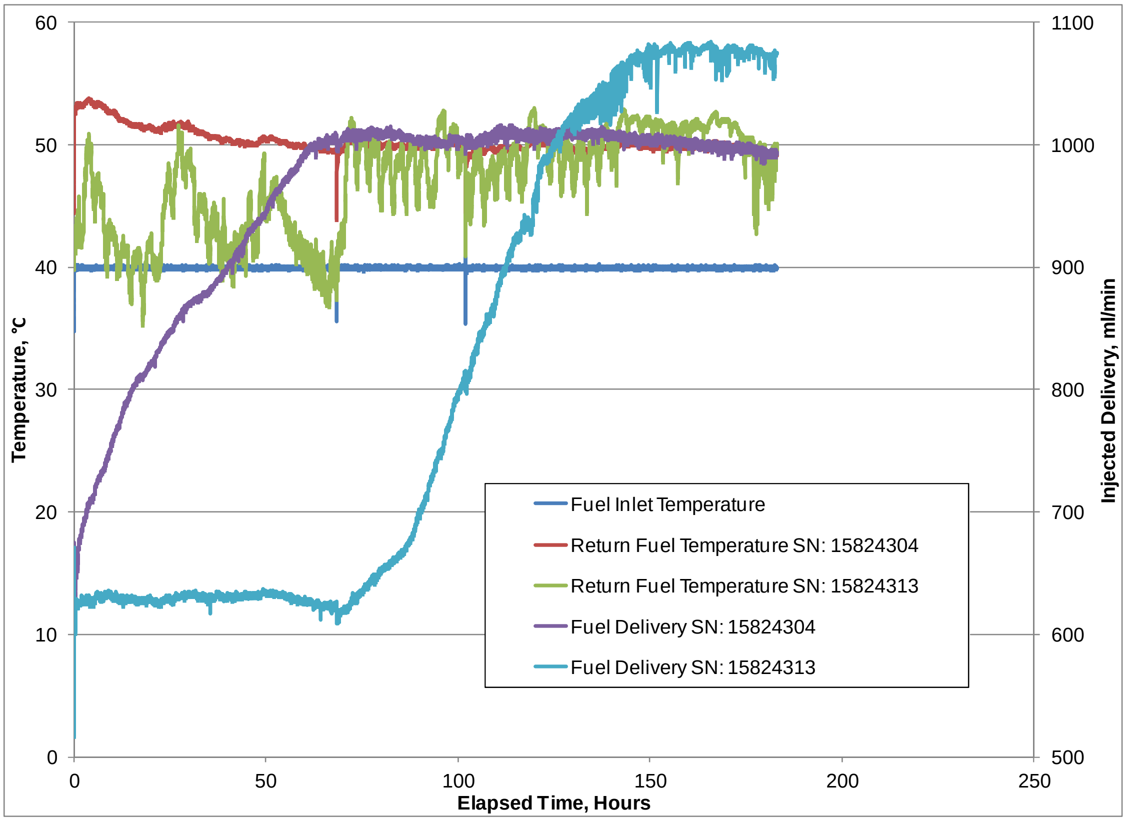


Figure C-7. Fuel Inlet, Fuel Return Temperatures and Fuel Flowrate Histories for R8+2.75-ppm DCI-4A Fuel

Figure C-8 shows the fuel pressure histories for the test with the R8 + 2.75-ppm DCI-4A fuel. The housing pressure for pumps SN: 15824304 and SN: 15824313 reveal a consistent increase throughout the 183-hours of operation. Usually wear in these pumps cause an increase in housing pressure due to internal leakage. The transfer pump pressure for pump SN: 15824304 revealed a steady decrease for the first 50-hours then reached a stabilized value. Pump SN: 15824313 reveals a steady average transfer pump pressure, with erratic pressure excursions, till about 75-hours of operation. From 75 to 125-hours of operation there is a steady decrease of transfer pump pressure for pump SN: 15824313. Both pumps revealed similar transfer pump pressures at the 183-hour termination of testing. At 183-hours of testing the tops of both fuel injection pumps were removed for inspection, and the pump housings were free of wear debris. Both fuel injection pumps had light brown staining, but were free from the heavy brown deposition that had previously been seen with the neat R8 fuel.

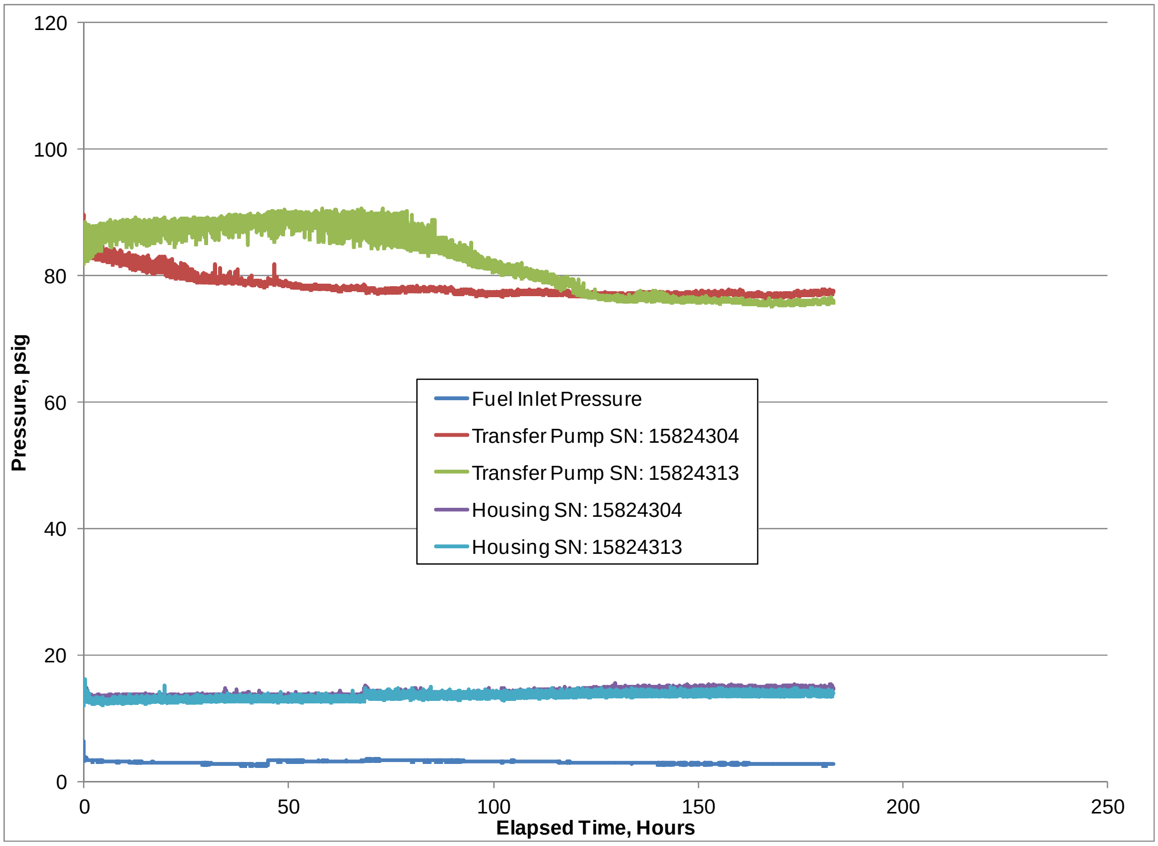


Figure C-8. Fuel Inlet, Transfer Pump, and Housing Pressure Histories for R8+2.75-ppm DCI-4A Fuel

C6.2 Rotary Pump Performance Measurements

Prior to the durability testing all the fuel injection pumps were run on an injection pump calibration stand to verify their performance with respect to their model number and application specification sheet. Although the pumps come from the factory set to meet their designated specification, because SwRI disassembles the pumps to take transfer pump blade measurements and roller-to-roller dimensions the fuel injection pumps performance is validated. At the conclusion of testing the fuel injection pumps are installed on the calibration stand and checked for performance changes due to the test fuel. There are not any adjustments made to the fuel injection pumps by the calibration personnel.

C6.2.1 R8 Fuel with 8.5-ppm DCI-4A CI/LI Additive

The Pre- and Post-Test performance curves for fuel injection pump SN: 15824298 are included as Table C-2. Items in shaded boxes in Table C-2 are values that fall outside of the specification for the fuel injection pump model. Red shading is for values above the specification maximums, blue shading for values below the specification minimums. At 1000-RPM the transfer pump pressure and return flow were above specification, the delivery volume had also decreased but there is not a minimum value specified at 1000-RPM. The delivery characteristics at 1000-RPM would likely impact the peak torque of the engine. At 1750-RPM and 1800-RPM the delivered quantity was out of specification which could lead to a reduction in engine peak power. The

results at 2025-RPM suggest the governor operation has been compromised for the SN: 15824298 pump on R8 + 8.5-ppm DCI-4A fuel. The minimum delivery values at 200-RPM and 75-RPM were not met; these conditions are significant for engine starting. The delivery at 75-RPM was zero, indicating an engine would not be able to start with pump SN: 15824298.

The Pre- and Post-Test performance curves for fuel injection pump SN: 15824300 are included as Table C-3. At 1000-RPM the return flow was above specification and the delivery volume had also decreased but there is not a minimum value specified at 1000-RPM. The delivery characteristics at 1000-RPM would likely impact the peak torque of the engine. At 350-RPM the low idle delivery had increased out of specification, which could impact idle speed and idle stability. At 1750-RPM and 1800-RPM the delivered quantity was out of specification which could lead to a reduction in engine peak power. The results at 2025-RPM suggest the governor operation was not compromised for the SN: 15824300 pump on R8 + 8.5-ppm DCI-4A fuel. The minimum delivery values at 200-RPM and 75-RPM were not met; these conditions are significant for engine starting. The delivery at 75-RPM was zero, indicating an engine would not be able to start with pump SN: 15824300.

Although both pumps were operational after 500-hours with the R8 + 8.5-ppm DCI-4A fuel, with a 0.75-mm BOCLE value, the pumps did not meet calibration performance criterion that would have impacted engine operability. It can be concluded that the R8 + 8.5-ppm DCI-4A fuel (0.75-mm BOCLE) has insufficient lubricity for rotary pump operation. Of interest the minimum effective concentration for DCI-4A, as defined by MIL-PRF-25017, is 9-ppm.

Table C-2. Injection Pump SN: 15824298 Performance Specifications

Stanadyne Pump Calibration / Evaluation

Pump Type : DB2831-5209 (arctic)				SN: 15824298	
Test condition :	500 hrs at 40°C and 1800-RPM WOT		Test: R8DCI8.5-C3UTC1-40-500		
Fuel:	Synthetic R8 with 8.5-ppm DCI-4A CI/LI additive				
PUMP RPM	***Description***	***Spec.***	***Before***	***After***	***Change***
1000	Transfer pump psi.	60-62 psi	62 psi	**66 psi**	-4 psi
	Return Fuel	225-375 cc	368 cc	**414 cc**	-46 cc
	Fuel Delivery	51.5 cc max.	51 cc	40 cc	11 cc
350	Low Idle	12-16 cc	14 cc	12 cc	2 cc
	Housing psi.	8-12 psi	11 psi	10.5 psi	0.5 psi
	Cold Advance Solenoid	0-1 deg.	0°	0°	0°
1750	Fuel Delivery	44.5-47.5 cc	45.0 cc	**37.0 cc**	8 cc
	Advance	3.75 - 4.75 deg.	4.26°	4.72°	-.46°
1900	Fuel Delivery	31.5 cc min.	38 cc	35 cc	3 cc
1600	Face Cam Fuel delivery	21.5 - 23.5 cc	22 cc	22 cc	0 cc
	Face Cam Advance	4 - 6 deg.	4.75°	4.20°	.55°
1800	Fuel Delivery	44 cc min.	45 cc	**36 cc**	9 cc
	Transfer Pump psi	Record	92 psi	99 psi	-7 psi
	Housing psi.	Record	11 psi	11 psi	0 psi
2025	High Idle	15 cc max.	2 cc	**18 cc**	-16 cc
	Transfer pump psi.	125 psi max.	112 psi	120 psi	-8 psi
200	WOT Fuel Delivery	40 cc min.	46 cc	**16 cc**	30 cc
	WOT Shut-Off	4 cc max.	0 cc	0 cc	0 cc
75	Low Idle Fuel Delivery	26 cc min.	35 cc	**0 cc**	35 cc
	Transfer pump psi.	16 psi min.	26 psi	24 psi	2 psi
	Air Timing	-1 deg.(+/-.5 deg)	-1.00°	**1.00°**	-2.00°
	Fluid Temp. Deg. C		38	38	
	Date		6/29/2012	8/31/2012	

Notes : Did Not Delver Fuel at Start-Up 75-RPM

Table C-3. Injection Pump SN: 15824300 Performance Specifications

Stanadyne Pump Calibration / Evaluation

Pump Type : DB2831-5209 (arctic)				SN: 15824300	
Test condition :	500 hrs at 40°C and 1800-RPM WOT		Test: R8DCI8.5-C3UTC1-40-499		
Fuel:	Synthetic R8 with 8.5-ppm DCI-4A CI/LI additive				
PUMP RPM	***Description***	***Spec.***	***Before***	***After***	***Change***
1000	Transfer pump psi.	60-62 psi	62 psi	62 psi	0 psi
	Return Fuel	225-375 cc	360 cc	**404 cc**	-44 cc
	Fuel Delivery	51.5 cc max.	52 cc	38 cc	14 cc
350	Low Idle	12-16 cc	15 cc	**18 cc**	-3 cc
	Housing psi.	8-12 psi	10 psi	10 psi	0 psi
	Cold Advance Solenoid	0-1 deg.	0°	0°	0°
1750	Fuel Delivery	44.5-47.5 cc	45.0 cc	**37.0 cc**	8 cc
	Advance	3.75 - 4.75 deg.	4.30°	3.84°	.46°
1900	Fuel Delivery	31.5 cc min.	38 cc	35 cc	3 cc
1600	Face Cam Fuel delivery	21.5 - 23.5 cc	22 cc	23 cc	-1 cc
	Face Cam Advance	4 - 6 deg.	4.15°	4.60°	-.45°
1800	Fuel Delivery	44 cc min.	44 cc	**36 cc**	9 cc
	Transfer Pump psi.	Record	94 psi	91 psi	3 psi
	Housing psi.	Record	11 psi	9 psi	2 psi
2025	High Idle	15 cc max.	6 cc	12 cc	-7 cc
	Transfer pump psi.	125 psi max.	105 psi	98 psi	7 psi
200	WOT Fuel Delivery	40 cc min.	43 cc	**22 cc**	21 cc
	WOT Shut-Off	4 cc max.	0 cc	0 cc	0 cc
75	Low Idle Fuel Delivery	26 cc min.	32 cc	**0 cc**	32 cc
	Transfer pump psi.	16 psi min.	21 psi	21 psi	0 psi
	Air Timing	-1 deg.(+/-.5 deg)	-1.00°	**.0°**	-1.0°
	Fluid Temp. Deg. C		38	38	
	Date		6/29/2012	8/31/2012	

Notes : Did Not Delver Fuel at Start-Up 75-RPM

C6.2.2 R8 Fuel with 2.75-ppm DCI-4A CI/LI Additive

The Pre- and Post-Test performance curves for fuel injection pump SN: 15824304 are included as Table C-4. Items in shaded boxes in Table C-4 are values that fall outside of the specification for the fuel injection pump model. Red shading is for values above the specification maximums, blue shading for values below the specification minimums. At 1000-RPM the delivery volume was above specification, the delivery characteristics at 1000-RPM would likely impact the peak torque of the engine, and with this pump an engine would exhibit increased black smoke. At low idle, 350-RPM, pump SN: 15824304 was below the minimum delivery value that could result in a rough engine idle. At 1750-RPM the delivered quantity was out of specification which could lead to an increase in engine power, at the cost of increased fuel consumption, increased black smoke and increased engine temperatures. The results at 2025-RPM suggest the governor operation had not been compromised for the SN: 15824298 pump on the R8+2.75-ppm DCI-4A fuel blend. The minimum delivery values at 200-RPM and 75-RPM were met, however the delivery values are grossly high, suggesting although an engine may start, white smoke would be an issue.

The Pre- and Post-Test performance curves for fuel injection pump SN: 15824313 are included as Table C-5. Items in shaded boxes in Table C-5 are values that fall outside of the specification for the fuel injection pump model. At 1000-RPM the transfer pump pressure was below the specification minimum, which could alter pump metering. At low idle, 350-RPM, pump SN: 15824313 was slightly below the minimum delivery value that may result in a rough engine idle. At 1750-RPM the delivered quantity and timing advance were out of specification which could lead to an increase in engine power, at the cost of increased fuel consumption, increased black smoke and increased engine temperatures. The 2025-RPM delivery result suggests the governor action is within specification for the SN: 15824313 pump on the R8+2.75-ppm DCI-4A fuel blend. The minimum delivery values that are critical for starting at 200-RPM and 75-RPM were also within specification, however the delivery values are grossly high, suggesting although an engine may start, white smoke would be an issue.

Both fuel injection pumps only completed 183-hours of operation with the R8 + 2.75-ppm DCI-4A fuel, with a 0.83-mm BOCLE value. Both pumps exhibited severe performance degradation with respect to their calibration performance criterion that would have impacted engine operability. It can be concluded that the R8 + 2.75-ppm DCI-4A fuel (0.83-mm BOCLE) has insufficient lubricity for rotary pump operation.

C6.3 Rotary Pump Wear Measurements

The transfer pump and plunger assemblies are integral to the fuel-metering system in the Stanadyne rotary pump, and by function are the most affected with low lubricity fuel. Accelerated wear in either the transfer pump blades or the roller-to-roller dimension results in a change of fueling condition that jeopardizes the quantity of fuel injected into the hydraulic head assembly. Wear in the transfer pump blades limits the amount of pressure necessary to maintain the proper amount of fuel in the chamber where opposing plungers, actuated by the rollers and cam, inject the metered fuel into the hydraulic head assembly. Roller-to-roller dimension variations alter the travel distance of the plungers, effectively changing metered fuel, injection pressure, and injection timing.

Table C-4. Injection Pump SN: 15824304 Performance Specifications

Stanadyne Pump Calibration / Evaluation

Pump Type : DB2831-5209 (arctic)				SN: 15824304	
Test condition :	183 hours at 40°C and 1800-RPM WOT		Test: R8DCI3-C4UTC2-40-500		
Fuel :	Synthetic R8 treated with 2.75-ppm DCI-4A CI/LI additive				
PUMP RPM	***Description***	***Spec.***	***Before***	***After***	***Change***
1000	Transfer pump psi.	60-62 psi	61 psi	58 psi	3 psi
	Return Fuel	225-375 cc	340 cc	360 cc	-20 cc
	Fuel Delivery	51.5 cc max.	51 cc	**80 cc**	-29 cc
350	Low Idle	12-16 cc	14 cc	**6.5 cc**	8 cc
	Housing psi.	8-12 psi	11 psi	10.5 psi	0.5 psi
	Cold Advance Solenoid	0-1 deg.	0°	0°	0°
1750	Fuel Delivery	44.5-47.5 cc	44.0 cc	**72.0 cc**	-28 cc
	Advance	3.75 - 4.75 deg.	4.21°	2.94°	1.27°
1900	Fuel Delivery	31.5 cc min.	39 cc	67 cc	-29 cc
1600	Face Cam Fuel delivery	21.5 - 23.5 cc	22 cc	22 cc	0 cc
	Face Cam Advance	4 - 6 deg.	4.47°	**6.02°**	-1.55°
1800	Fuel Delivery	44 cc min.	44 cc	70 cc	-26 cc
	Transfer Pump psi	Record	94 psi	84 psi	10 psi
	Housing psi.	Record	11 psi	11 psi	0 psi
2025	High Idle	15 cc max.	2.0 cc	7.5 cc	-5.5 cc
	Transfer pump psi.	125 psi max.	107 psi	110 psi	-3 psi
200	WOT Fuel Delivery	40 cc min.	45 cc	74 cc	-29 cc
	WOT Shut-Off	4 cc max.	0 cc	0 cc	0 cc
75	Low Idle Fuel Delivery	26 cc min.	32 cc	60 cc	-28 cc
	Transfer pump psi.	16 psi min.	20 psi	24 psi	-4 psi
	Air Timing	-1 deg.(+/-.5 deg)	-1.00°	1.00°	-2.00°
	Fluid Temp. Deg. C		38	38	
	Date		7/10/2012	8/15/2012	

Notes :

Table C-5. Injection Pump SN: 15824313 Performance Specifications

Stanadyne Pump Calibration / Evaluation

Pump Type : DB2831-5209 (arctic)				SN: 15824313	
Test condition :	183 hours at 40°C and 1800-RPM WOT		Test: R8DCI3-C4UTC2-40-500		
Fuel :	Synthetic R8 treated with 2.75-ppm DCI-4A CI/LI additive				
PUMP RPM	***Description***	***Spec.***	***Before***	***After***	***Change***
1000	Transfer pump psi.	60-62 psi	62 psi	**59 psi**	3
	Return Fuel	225-375 cc	252 cc	278 cc	-26 cc
	Fuel Delivery	51.5 cc max.	50 cc	86 cc	-36 cc
350	Low Idle	12-16 cc	15 cc	**10 cc**	6 cc
	Housing psi.	8-12 psi	12 psi	10.5 psi	1.5 psi
	Cold Advance Solenoid	0-1 deg.	0°	0°	0°
1750	Fuel Delivery	44.5-47.5 cc	45.0 cc	**74.0 cc**	-29.0 cc
	Advance	3.75 - 4.75 deg.	4.25°	**2.32°**	1.93°
1900	Fuel Delivery	31.5 cc min.	37 cc	72 cc	-35 cc
1600	Face Cam Fuel delivery	21.5 - 23.5 cc	21 cc	22 cc	-1 cc
	Face Cam Advance	4 - 6 deg.	4.66°	4.98°	-.32°
1800	Fuel Delivery	44 cc min.	44 cc	74 cc	-30 cc
	Transfer Pump psi.	Record	95 psi	85 psi	10 psi
	Housing psi.	Record	12 psi	11 psi	1 psi
2025	High Idle	15 cc max.	3 cc	3 cc	cc
	Transfer pump psi.	125 psi max.	111 psi	111 psi	0 psi
200	WOT Fuel Delivery	40 cc min.	44 cc	81 cc	-37 cc
	WOT Shut-Off	4 cc max.	0 cc	0 cc	0 cc
75	Low Idle Fuel Delivery	26 cc min.	32 cc	65	-33 cc
	Transfer pump psi.	16 psi min.	25 psi	23 psi	2 psi
	Air Timing	-1 deg.(+/-.5 deg)	-1.00°	.0°	-1.0°
	Fluid Temp. Deg. C		38	38	
	Date		7/10/2012	8/15/2012	

Notes :

C6.3.1 R8 Fuel with 8.5-ppm DCI-4A CI/LI Additive

Table C-6 and Table C-7 present the transfer pump blade and roller-to-roller dimension measurement results for the two fuel injection pumps that operated on R8 + 8.5-ppm DCI-4A fuel. There was not any out-of-specification transfer blade measurements based on the dimension length C for either pump SN: 15824298 or SN: 15824300. Unlike the neat R8 fuel test, the width of the blades did not change dramatically, nor did the blades thicknesses decrease much. The blade width and blade thickness did decrease more than the R8 testing with maximum CI/LI treatment and the R8/Jet-A blend with maximum CI/LI treatment. Both pump roller-to-roller dimensions changes were less than the ± 0.005-inch assembly specification tolerance. However the roller-to-roller dimensions did decrease for both pumps, as reflected in the decreased delivery seen for both pumps. The roller-to-roller eccentricity specification is 0.008-inch maximum, of which both pumps met for testing with the R8 + 8.5-ppm DCI-4A fuel at 500-hours. In general all transfer pump blades were in good condition, and the roller-to-roller dimensions changes reflect the performance changes seen on the calibration stand.

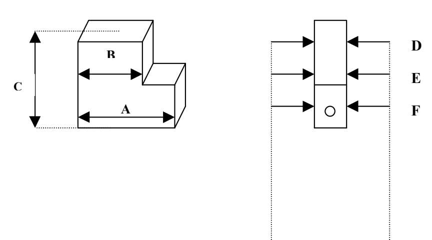
Table C-6. Pump SN: 15824298 Blade Size Measurements

Blade & Roller-To-Roller Measurements

Pump Type : DB2831-5209	SN: 15824298	Test Number : R8DCI8.5-C3UTC1-40-500
Fuel description : Synthetic R8 with 8.5-ppm DCI-4A CI/LI additive		

	Date:	6/21/2012	9/13/2012	
Dimensional Measurements (mm)		***0 hrs.***	***500 hrs.***	***Change***
Transfer Pump Blade 1	Dimension A	13.7617	13.7566	-0.0051
	Dimension B	9.9974	9.9898	-0.0076
	Dimension C	12.6695	12.6670	-0.0025
	Dimension D	3.1585	3.1509	-0.0076
	Dimension E	3.1585	3.1521	-0.0064
	Dimension F	3.1585	3.1560	-0.0025
Transfer Pump Blade 2	Dimension A	13.7516	13.7465	-0.0051
	Dimension B	10.0051	10.0000	-0.0051
	Dimension C	12.6695	12.6670	-0.0025
	Dimension D	3.1585	3.1547	-0.0038
	Dimension E	3.1610	3.1572	-0.0038
	Dimension F	3.1610	3.1572	-0.0038
Transfer Pump Blade 3	Dimension A	13.7668	13.7630	-0.0038
	Dimension B	10.0368	10.0343	-0.0025
	Dimension C	12.6657	12.6632	-0.0025
	Dimension D	3.1547	3.1509	-0.0038
	Dimension E	3.1572	3.1521	-0.0051
	Dimension F	3.1547	3.1521	-0.0025
Transfer Pump Blade 4	Dimension A	13.7465	13.7414	-0.0051
	Dimension B	10.0343	10.0317	-0.0025
	Dimension C	12.6797	12.6746	-0.0051
	Dimension D	3.1560	3.1547	-0.0013
	Dimension E	3.1598	3.1572	-0.0025
	Dimension F	3.1598	3.1585	-0.0013
	Roller to Roller (in)	1.9625	1.9579	-0.0046
	Eccentricity (in.)	0.0070	0.0050	-0.0020
	Drive Backlash (In)	0.0030	0.0240	0.0210

	MIN - HEIGHT (C)	MAX - HEIGHT (C)
Inches	0.4986	0.4993
Millimeters	12.66444	12.68222



- A- Blade length approximately 13.77mm
- B- Blade length approximately 9.95mm
- C- Blade height approximately 12.66mm

Blade Thickness / width approximately 3.11mm

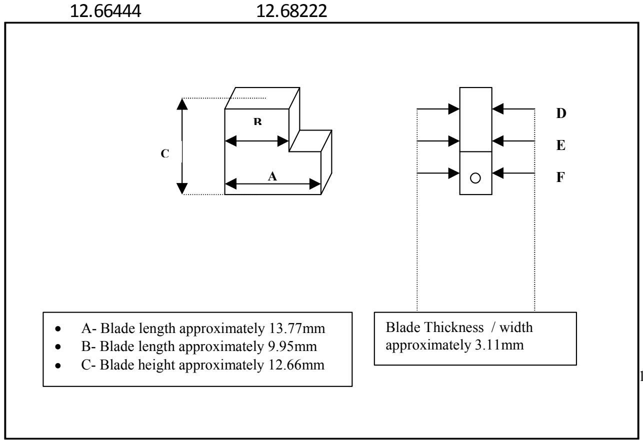
Table C-7. Pump SN: 15824300 Blade Size Measurements

Blade & Roller-To-Roller Measurements

Pump Type : DB2831-5209	SN: 15824300	Test Number : R8DCI8.5-C3UTC1-40-500
Fuel description : Synthetic R8 with 8.5-ppm DCI-4A CI/LI additive		

	Date:	6/21/2012	9/13/2012	
Dimensional Measurements (mm)		***0 hrs.***	***500 hrs.***	***Change***
Transfer Pump Blade 1	Dimension A	13.7732	13.7655	-0.0076
	Dimension B	10.0419	10.0355	-0.0063
	Dimension C	12.6695	12.6695	0.0000
	Dimension D	3.1267	3.1217	-0.0051
	Dimension E	3.1255	3.1217	-0.0038
	Dimension F	3.1255	3.1204	-0.0051
Transfer Pump Blade 2	Dimension A	13.7287	13.7211	-0.0076
	Dimension B	10.0127	10.0063	-0.0063
	Dimension C	12.6695	12.6670	-0.0025
	Dimension D	3.1293	3.1267	-0.0025
	Dimension E	3.1293	3.1267	-0.0025
	Dimension F	3.1280	3.1267	-0.0013
Transfer Pump Blade 3	Dimension A	13.8113	13.8011	-0.0102
	Dimension B	10.0571	10.0432	-0.0140
	Dimension C	12.6695	12.6683	-0.0013
	Dimension D	3.1255	3.1242	-0.0013
	Dimension E	3.1255	3.1229	-0.0025
	Dimension F	3.1255	3.1217	-0.0038
Transfer Pump Blade 4	Dimension A	13.7820	13.7732	-0.0089
	Dimension B	9.9835	9.9708	-0.0127
	Dimension C	12.6708	12.6695	-0.0013
	Dimension D	3.1242	3.1229	-0.0013
	Dimension E	3.1242	3.1229	-0.0013
	Dimension F	3.1255	3.1217	-0.0038
	Roller to Roller (in)	1.9620	1.9580	-0.0040
	Eccentricity (in.)	0.0070	0.0050	-0.0020
	Drive Backlash (In)	0.0030	0.0240	0.0210

	MIN - HEIGHT (C)	MAX - HEIGHT (C)
Inches	0.4986	0.4993
Millimeters	12.66444	12.68222



C6.3.2 R8 Fuel with 2.75-ppm DCI-4A CI/LI Additive

Table C-8 and Table C-9 present the transfer pump blade and roller-to-roller dimension measurement results for the two fuel injection pumps that operated on the R8 + 2.75-ppm DCI-4A fuel blend. There was not any out-of-specification transfer blade measurements based on the dimension length C for either pump SN: 15824304 or SN: 15824313. Again, unlike the neat R8 fuel test, the width of the blades did not change dramatically, nor did the blades thicknesses decrease much. However considering only 183-hours of operation, some of the dimensional changes do appear significant, and may have affected transfer pump operation. Both pump SN: 15824304 and SN: 15824313 roller-to-roller dimensions increased, changing substantially more than the ± 0.005-inch assembly specification tolerance. The roller-to-roller dimensions increase for both pumps is reflected in the greatly increased delivery seen for both pumps. The roller-to-roller eccentricity specification is 0.008-inch maximum, of which neither pump exceeded the value after 183-hours testing with the R8 + 2.75-ppm DCI-4A fuel blend. In general all transfer pump blades were in good condition, and the roller-to-roller dimensions changes reflected the performance changes seen on the calibration stand.

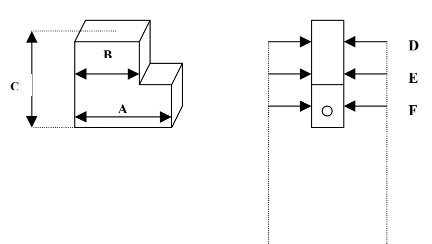
Table C-8. Pump SN: 15824304 Blade Size Measurements

Blade & Roller-To-Roller Measurements

Pump Type : DB2831-5209	SN: 15824304	Test Number : R8DCI3-C4UTC2-40-500
Fuel description : Synthetic R8 with 2.75-ppm DCI-4A CI/LI additive		

Dimensional Measurements (mm)	Date:	7/2/2012	9/12/2012	
		0 hrs.	**183 hrs.**	**Change**
Transfer Pump Blade 1	Dimension A	13.7884	13.7833	-0.0051
	Dimension B	9.9962	9.9911	-0.0051
	Dimension C	12.6695	12.6683	-0.0013
	Dimension D	3.1267	3.1217	-0.0051
	Dimension E	3.1267	3.1217	-0.0051
	Dimension F	3.1255	3.1217	-0.0038
Transfer Pump Blade 2	Dimension A	13.7884	13.7833	-0.0051
	Dimension B	10.0508	10.0470	-0.0038
	Dimension C	12.6657	12.6657	0.0000
	Dimension D	3.1267	3.1242	-0.0025
	Dimension E	3.1267	3.1242	-0.0025
	Dimension F	3.1267	3.1255	-0.0013
Transfer Pump Blade 3	Dimension A	13.7846	13.7795	-0.0051
	Dimension B	10.0114	10.0076	-0.0038
	Dimension C	12.6670	12.6657	-0.0013
	Dimension D	3.1255	3.1242	-0.0013
	Dimension E	3.1255	3.1242	-0.0013
	Dimension F	3.1255	3.1242	-0.0013
Transfer Pump Blade 4	Dimension A	13.7071	13.7020	-0.0051
	Dimension B	9.9428	9.9365	-0.0064
	Dimension C	12.6771	12.6759	-0.0013
	Dimension D	3.1267	3.1255	-0.0013
	Dimension E	3.1267	3.1255	-0.0013
	Dimension F	3.1267	3.1255	-0.0013
	Roller to Roller (in)	1.9621	1.9876	0.0255
	Eccentricity (in.)	0.0000	0.0030	0.0030
	Drive Backlash (In)	0.0040	0.0060	0.0020

	MIN - HEIGHT (C)	MAX - HEIGHT (C)
Inches	0.4986	0.4993
Millimeters	12.66444	12.68222



- A- Blade length approximately 13.77mm
- B- Blade length approximately 9.95mm
- C- Blade height approximately 12.66mm

Blade Thickness / width approximately 3.11mm

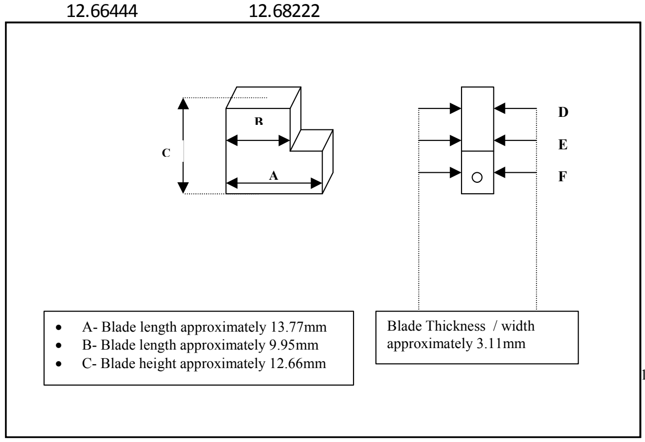
Table C-9. Pump SN: 15824313 Blade Size Measurements

Blade & Roller-To-Roller Measurements

Pump Type : DB2831-5209	SN: 15824313	Test Number : R8DCI3-C4UTC2-40-500
Fuel description : Synthetic R8 with 2.75-ppm DCI-4A CI/LI additive		

	Date:	7/2/2012	9/12/2012	
Dimensional Measurements (mm)		***0 hrs.***	***183 hrs.***	***Change***
Transfer Pump Blade 1	Dimension A	13.7414	13.7389	-0.0025
	Dimension B	9.9911	9.9797	-0.0114
	Dimension C	12.6733	12.6721	-0.0013
	Dimension D	3.1306	3.1293	-0.0013
	Dimension E	3.1306	3.1293	-0.0013
	Dimension F	3.1293	3.1280	-0.0013
Transfer Pump Blade 2	Dimension A	13.8036	13.7998	-0.0038
	Dimension B	10.0292	10.0190	-0.0102
	Dimension C	12.6695	12.6632	-0.0064
	Dimension D	3.1293	3.1280	-0.0013
	Dimension E	3.1280	3.1280	0.0000
	Dimension F	3.1280	3.1255	-0.0025
Transfer Pump Blade 3	Dimension A	13.7414	13.7300	-0.0114
	Dimension B	9.9797	9.9733	-0.0064
	Dimension C	12.6721	12.6695	-0.0025
	Dimension D	3.1331	3.1293	-0.0038
	Dimension E	3.1318	3.1280	-0.0038
	Dimension F	3.1318	3.1280	-0.0038
Transfer Pump Blade 4	Dimension A	13.7033	13.7008	-0.0025
	Dimension B	9.9022	9.8971	-0.0051
	Dimension C	12.6708	12.6708	0.0000
	Dimension D	3.1318	3.1280	-0.0038
	Dimension E	3.1306	3.1267	-0.0038
	Dimension F	3.1306	3.1267	-0.0038
	Roller to Roller (in)	1.9621	1.9878	0.0257
	Eccentricity (in.)	0.0000	0.0010	0.0010
	Drive Backlash (In)	0.0050	0.0090	0.0040

	MIN - HEIGHT (C)	MAX - HEIGHT (C)
Inches	0.4986	0.4993
Millimeters	12.66444	12.68222



C6.4 Fuel Injector Results

Fuel injector nozzle tests were performed in accordance with procedures set forth in an approved 6.5L diesel engine manual using diesel nozzle tester J 29075 – B. Nozzle testing is comprised of the following checks:

- Nozzle Opening Pressure
- Leakage
- Chatter
- Spray Pattern

Each test is considered independent of the others, and if any one of the tests is not satisfied, the injector should be replaced.

The normal opening pressure specification for these injectors is 1500 psig minimum. The specified nozzle leakage test involves pressurizing the injector nozzle to 1400 psig and holding for 10 seconds – no fuel droplets should separate from the injector tip. The chatter and spray pattern evaluations are subjective. A sharp audible chatter from the injector and a finely misted spray cone are required.

New Bosch Model O432217104 injectors were used for both of the R8 + CI/LI additive fuel tests. The injector performance tests and rating results are shown in Table C-10 for the R8 + 8.5-ppm DCI-4A test. Fifteen of the fuel injectors passed the post-test opening pressure evaluations after 500-hours of operation. One fuel injector, UTC1-13 on pump SN: 15824298 exhibited a sticking needle that impacted opening pressure.

The injector performance tests and rating results are shown in Table C-11 for the R8 + 2.75-ppm DCI-4A test. Four injectors failed to meet the minimum nozzle opening pressure after 183-hours of operation. With the R8 + 2.75-ppm DCI-4A fuel blend, eight of the injectors revealed tip leakage after 183-hours of operation. Injector tip leakage could cause increased smoke emission upon engine start, and increased unburned hydrocarbon and carbon monoxide emissions. Five fuel injectors exhibited failed chatter and spray performance due to needle stickiness or sluggishness.

Table C-10. Fuel Injector Performance Evaluations after 500-Hours R8 + 8.5-ppm DCI-4A CI/LI Fuel Usage

Stanadyne Rotary Pump Lubricity Evaluation

6.2L/6.5L Fuel Injector Test Inspection

Test No.	Inj. Pump ID No.	Fuel	Inj. ID No.	Opening Pressure (pre-test)	Opening Pressure (post-test)	Tip Leakage (pre-test)	Tip Leakage (post-test)	Chatter (pre-test)	Chatter (post-test)	Spray pattern (pre-test)	Spray pattern (post-test)	Date (pre-test)	Date (post-test)	Test Hours	Tech.
R8DCI8.5-C3UTC1-40-500	SN: 15824300	Synthetic R8 with 8.5-ppm DCI-4A CI/LI additive	UTC1-1	1950	1525	pass	wet	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-2	1900	1500	pass	fail	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-3	1950	1600	pass	pass	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-4	1900	1525	pass	wet	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-5	1950	1525	pass	fail	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-6	1950	1600	pass	pass	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-7	1900	1525	pass	pass	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-8	2000	1625	pass	pass	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
R8DCI8.5-C3UTC1-40-500	SN:15824298	Synthetic R8 with 8.5-ppm DCI-4A CI/LI additive	UTC1-9	1925	1475	pass	fail	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-10	1900	1525	pass	pass	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-11	1900	1550	pass	pass	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-12	1900	1525	pass	fail	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-13	1950	800	pass	fail	pass	fail	pass	fail	6/26/2012	9/5/2012	500	REG
			UTC1-14	1950	1675	pass	wet	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-15	1875	1525	pass	fail	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			UTC1-16	1950	1575	pass	pass	pass	pass	pass	pass	6/26/2012	9/5/2012	500	REG
			Spec. :	1500psig min	1500psig min	no drop off in 10 sec. @ 1400 psi	no drop off in 10 sec. @ 1400 psi	chatter	chatter	fine mist	fine mist				

Comments : UTC1-13 had a stuck needle after 500-hours testing

Table C-11. Fuel Injector Performance Evaluations after 183-Hours R8 + 2.75-ppm DCI-4A CI/LI Fuel Usage

Stanadyne Rotary Pump Lubricity Evaluation

6.2L/6.5L Fuel Injector Test Inspection

Test No.	Inj. Pump ID No.	Fuel	Inj. ID No.	Opening Pressure (pre-test)	Opening Pressure (post-test)	Tip Leakage (pre-test)	Tip Leakage (post-test)	Chatter (pre-test)	Chatter (post-test)	Spray pattern (pre-test)	Spray pattern (post-test)	Date (pre-test)	Date (post-test)	Test Hours	Tech.
R8DCI3-C4UTC2-40-500	SN: 15824313	Synthetic R8 with 2.75-ppm DCI-4A CI/LI additive	UTC2-1	1900	1400	pass	fail	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-2	1925	1500	pass	fail	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-3	1975	1675	pass	pass	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-4	1875	1550	pass	pass	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-5	1900	1475	pass	fail	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-6	1900	1400	pass	fail	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-7	1875	1575	pass	fail	pass	fail	pass	fail	6/27/2012	9/5/2012	183	REG
			UTC2-8	1950	1600	pass	pass	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
R8DCI3-C4UTC2-40-500	SN:15824304	Synthetic R8 with 2.75-ppm DCI-4A CI/LI additive	UTC2-9	1900	1600	pass	fail	pass	fail	pass	fail	6/27/2012	9/5/2012	183	REG
			UTC2-10	1925	1625	pass	pass	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-11	1925	1625	pass	pass	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-12	1925	1550	pass	pass	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			UTC2-13	1875	1475	pass	fail	pass	fail	pass	fail	6/27/2012	9/5/2012	183	REG
			UTC2-14	1925	1700	pass	pass	pass	fail	pass	fail	6/27/2012	9/5/2012	183	REG
			UTC2-15	1925	1625	pass	pass	pass	fail	pass	fail	6/27/2012	9/5/2012	183	REG
			UTC2-16	1900	1525	pass	fail	pass	pass	pass	pass	6/27/2012	9/5/2012	183	REG
			Spec. :	1500psig min	1500psig min	no drop off in 10 sec. @ 1400 psi	no drop off in 10 sec. @ 1400 psi	chatter	chatter	fine mist	fine mist				

Comments : UTC2-7, UTC2-9, UTC2-13, UTC2-14, UTC2-15 each had a sticking/sluggish needle after 183-hours testing

C6.5 Rotary Pump Component Wear Evaluation

After the fuel injection pump calibration and functional performance checks, the fuel injection pumps are disassembled and the components critical to pump operation are evaluated for parts conditions. A technician with over twenty years experience rebuilding, servicing, and testing Stanadyne fuel injection pumps performs the subjective wear rating.

C6.5.1 R8 Fuel with 8.5-ppm DCI-4A CI/LI Additive – Pump SN: 15824298

The parts conditions and subjective wear ratings for fuel injection pump SN: 15824298 are summarized in Table C-12. Images of the wear seen on the components of fuel injection pump SN: 15824298 are shown in Figure C-9 through Figure C-26. Figure C-9 and Figure C-10 show the condition of the injection pump rotor that carries the plungers and distributes the compressed fuel. Figure C-9 and Figure C-10 reveal the light scratches at the rotor discharge ports, usually from wear debris, after the 500-hours.

Figure C-11 and Figure C-12 is the Pre-Test and Post-Test conditions of fuel injection pump SN: 15824298 Roller Shoe and Roller conditions. Of note is the lack of a wear scar at the roller shoe leaf spring contact and the shiny, bright rollers shown in Figure C-11. Figure C-12 reveals only light polishing wear on the roller shoe from the leaf spring contact, and light burnishing on the rollers. The rollers tend to discolor when combination rolling-sliding action occurs as the rollers follow the injection cam profile. Figure C-13 and Figure C-14 show the relatively small wear scar due to 500-hours operation on the roller shoe plunger contact. The wear seen in Figure C-14 is typical for a marginal lubricity fuel. The injection pump cam ring shown in Figure C-15 and Figure C-16 does not reveal any distress from 500-hours operation with the R8 + 8.5-ppm DCI-4A fuel.

The governor thrust washer condition before and after 500-hours are shown in Figure C-17 and Figure C-18. The polishing wear seen on the thrust washer in Figure C-18 is typical for 500-hours of injection pump operation. Scoring wear seen on the advance piston suggests the fuel pressure may have been fluctuating in that area of the fuel injection pumps housing. The metering valve regulates the pressure to the rotor fill ports. The pressure is regulated by the action of the helix changing the outlet area of an orifice. Due to WOT operation a lightly polished area shows at one location on the helix. The wear on these components is normal considering the 500-hour duration of testing. The wear on the thrust washer, the advance piston wear, and the metering valve did not have an effect on pump operation.

Table C-12. Pump SN: 15824298 Component Wear Ratings

Stanadyne pump parts Evaluation

Pump Type : DB2831-5209	**SN: 15824298**
Test condition : 500 Hours at Fuel Inlet Temperature 40°C and 1800-RPM WOT	**TEST: R8DCI8.5-C3UTC1-40-500**

Part Name	Condition of part	Rating 0 = New 5 = Failed
BLADES	Wear at rotor slots and liner contact (oversized)	2.5
BLADE SPRINGS	Rubbing wear	1
LINER	80% scoring wear	3
TRANSFER PUMP REGULATOR	Wear mark from rotor contact, light polishing	1.5
REGULATOR PISTON	Polishing wear, light scoring	2.5
ROTOR	Wear mark (radial) at distributor port	3
ROTOR RETAINERS	Wear from rotor contact	2.5
DELIVERY VALVE	Polishing wear (oversized)	2
PLUNGERS	Polishing wear (oversized)	1.5
SHOES	Light wear from leaf spring contact, light scuffing on left shoe, dimple on backs	2
ROLLERS	Discolored - normal wear	1.5
LEAF SPRING	Wear from shoe contact	2.5
CAM RING	Normal	1
THRUST WASHER	Polishing wear	1.5
THRUST SLEEVE	Wear from governor arm fingers, brown stains, wear from governor weights	2
GOVORNER WEIGHTS	Brown stains/deposits, wear from thrust washer contact	2
LINK HOOK	Fingers worn excessively, dimple on arm at fulcrum pivot point	3
METERING VAVLE	Brown deposits, polishing wear	1.5
DRIVE SHAFT TANG	Fretting and chattering wear	3.5
DRIVE SHAFT SEALS	Normal	1
CAM PIN	Normal, in specification	1
ADVANCE PISTON	Scoring wear	3.5
HOUSING	Brown stains/deposits, wear from thrust washer contact	1
	AVERAGE DEMERIT RATINGS	2.02

Figure C-19 and Figure C-20 illustrates the minor level of wear seen in the transfer pump section of fuel injection pump SN: 15824298. Figure C-19 shows the surface condition of the transfer pump liner prior to testing and Figure C-20 shows the surface with light polishing after 500-hours of operation on the R8 + 8.5-ppm DCI-4A fuel. Also illustrative of the transfer pump section wear are the transfer pump blade conditions shown in Figure C-21 through Figure C-24

light edge wear shown in Figure C-21 and Figure C-22 corresponds to the surface on the transfer pump blades that contact and slide on the transfer pump liner, separated by a film of fuel. The side scuffing shown in Figure C-23 and Figure C-24 reflect wear from the transfer pump blade slots on the injection pump rotor. The wear seen on the transfer pump components is substantially reduced from the neat R8 fuel testing due to the presence of the CI/LI additive in pump SN: 15824298.

Figure C-25 and Figure C-26 show the condition of the injection pump drive shaft drive tang that transmits torque to the hydraulic section of the pump from the engine. Figure C-25 and Figure C-26 reveal a wear scar that indicates backlash and timing were likely altered with the R8 + 8.5-ppm DCI-4A fuel after 500-hours.

Figure C-9. Pump SN: 15824298 Distributor Rotor before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-10. Pump SN: 15824298 Distributor Rotor with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-11. Pump SN: 15824298 Rollers and Shoe before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-12. Pump SN: 15824298 Rollers and Shoe with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-13. Pump SN: 15824298 Roller Shoe before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-14. Pump SN: 15824298 Roller Shoe with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-15. Pump SN: 15824298 Cam Ring before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-16. Pump SN: 15824298 Cam Ring with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-17. Pump SN: 15824298 Thrust Washer before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-18. Pump SN: 15824298 Thrust Washer with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-19. Pump SN: 15824298 Transfer Pump Liner before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-20. Pump SN: 15824298 Transfer Pump Liner with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-21. Pump SN: 15824298 Transfer Pump Blade Edges before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-22. Pump SN: 15824298 Transfer Pump Blade Edges with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-23. Pump SN: 15824298 Transfer Pump Blade Sides before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-24. Pump SN: 15824298 Transfer Pump Blade Sides with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-25. Pump SN: 15824298 Driveshaft Drive Tang before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-26. Pump SN: 15824298 Driveshaft Drive Tang with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

C6.5.2 R8 Fuel with 8.5-ppm DCI-4A CI/LI Additive – Pump SN: 15824300

The parts conditions and subjective wear ratings for fuel injection pump SN: 15824300 are summarized in Table C-13. Images of the wear seen on the components of fuel injection pump SN: 15824300 are shown in Figure C-27 through Figure C-44. Figure C-27 and Figure C-28 show the condition of the injection pump rotor that carries the plungers and distributes the compressed fuel. Figure C-28 reveals the very light scratches at the rotor discharge ports, usually from wear debris, after the 500-hours.

Figure C-29 and Figure C-30 is the Pre-Test and Post-Test conditions of fuel injection pump SN: 15824300 Roller Shoe and Roller conditions. Of note is the lack of a wear scar at the roller shoe leaf spring contact and the shiny, bright rollers shown in Figure C-29. Figure C-30 reveals only light polishing wear on the roller shoe from the leaf spring contact, and light burnishing on the rollers. The rollers tend to discolor when combination rolling-sliding action occurs as the rollers follow the injection cam profile. Figure C-31 and Figure C-32 show the wear scar due to 500-hours operation on the roller shoe plunger contact. The heavy wear seen in Figure C-32 is typical for a marginal lubricity fuel. The injection pump cam ring shown in Figure C-33 and Figure C-34 does not reveal any distress from 500-hours operation with the R8 + 8.5-ppm DCI-4A fuel.

The governor thrust washer condition before and after 500-hours is seen in Figure C-35 and Figure C-36. The polishing wear seen on the thrust washer in Figure C-36 is again typical for 500-hours of injection pump operation. Scoring wear seen on the advance piston suggests the fuel pressure may have been fluctuating in that area of the fuel injection pumps housing. The

metering valve regulates the pressure to the rotor fill ports. The pressure is regulated by the action of the helix changing the outlet area of an orifice. Due to WOT operation a lightly polished area shows at one location on the helix. The wear on these components is normal considering the 500-hour duration of testing. The wear on the thrust washer, the advance piston wear, and the metering valve did not have an effect on pump operation.

Figure C-37 and Figure C-38 illustrates the minor level of wear seen in the transfer pump section of fuel injection pump SN: 15824300. Figure C-37 shows the surface condition of the transfer pump liner prior to testing and Figure C-38 shows the surface with light polishing after 500-hours of operation on the R8 + 8.5-ppm DCI-4A fuel. Also illustrative of the transfer pump section wear are the transfer pump blade conditions shown in Figure C-39 through Figure C-42. The light edge wear shown in Figure C-39 and Figure C-40 corresponds to the surface on the transfer pump blades that contact the transfer pump liner. The side scuffing shown in Figure C-41 and Figure C-42 reflect wear from the transfer pump blade slots on the injection pump rotor. The wear seen on the transfer pump components is substantially reduced from the neat R8 fuel testing due to the presence of the CI/LI additive in pump SN: 15824300.

Figure C-43 and Figure C-44 show the condition of the injection pump drive shaft drive tang that transmits torque to the hydraulic section of the pump from the engine. Figure C-44 reveals a wear scar that indicates backlash and timing were likely altered with the R8 + 8.5-ppm DCI-4A fuel after 500-hours. For both pumps that utilized the R8 + 8.5-ppm DCI-4A fuel, there were not any significantly worn components that could be considered the sole source of the injection pump performance degradation. The cumulative effect of all the worn components likely contributed to the degradation with the R8 + 8.5-ppm DCI-4A (0.75-mm BOCLE) fuel.

Figure C-27. Pump SN: 15824300 Distributor Rotor before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-28. Pump SN: 15824300 Distributor Rotor with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Table C-13. Pump SN: 15824300 Component Wear Ratings

Stanadyne pump parts Evaluation

Pump Type : DB2831-5209	**SN: 15824300**
Test condition : 500 Hours at Fuel Inlet Temperature 40°C and 1800-RPM WOT	**TEST: R8DCI8.5-C3UTC1-40-500**

Part Name	Condition of part	Rating 0 = New 5 = Failed
BLADES	Wear at rotor slots and liner contact (standard)	2
BLADE SPRINGS	Rubbing wear	2
LINER	80% scoring wear	3
TRANSFER PUMP REGULATOR	Wear mark from rotor contact, light polishing	1.5
REGULATOR PISTON	Polishing wear	1
ROTOR	Radial wear marks at distributor and inlet ports	2.5
ROTOR RETAINERS	Wear from rotor contact	2.5
DELIVERY VALVE	Broken spring and Polishing wear	2
PLUNGERS	Polishing wear	1.5
SHOES	Light wear from leaf spring contact, heavy dimple on left shoe back	2.5
ROLLERS	Discolored - normal wear	1.5
LEAF SPRING	Wear from shoe contact	2.5
CAM RING	Minor pitting at roller contact points, light polishing	1.5
THRUST WASHER	Polishing wear	1.5
THRUST SLEEVE	Normal	1
GOVORNER WEIGHTS	Weight retainer loose, wear from thrust washer contact	1.5
LINK HOOK	Fingers worn excessively, dimple on arm at fulcrum pivot point	2.5
METERING VAVLE	Brown deposits, polishing wear	1.5
DRIVE SHAFT TANG	Fretting and chattering wear	3
DRIVE SHAFT SEALS	Normal	1
CAM PIN	Normal, in specification	1
ADVANCE PISTON	Scoring wear	3
HOUSING	Light brown deposits	1
	AVERAGE DEMERIT RATINGS	1.87

Figure C-29. Pump SN: 15824300 Rollers and Shoe Condition before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-30. Pump SN: 15824300 Rollers and Shoe with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-31. Pump SN: 15824300 Roller Shoe Condition before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-32. Pump SN: 15824300 Roller Shoe with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-33. Pump SN: 15824300 Cam Ring Before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-34. Pump SN: 15824300 Cam Ring with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-35. Pump SN: 15824300 Thrust Washer Before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-36. Pump SN: 15824300 Thrust Washer with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-37. Pump SN: 15824300 Transfer Pump Liner before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-38. Pump SN: 15824300 Transfer Pump Liner with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

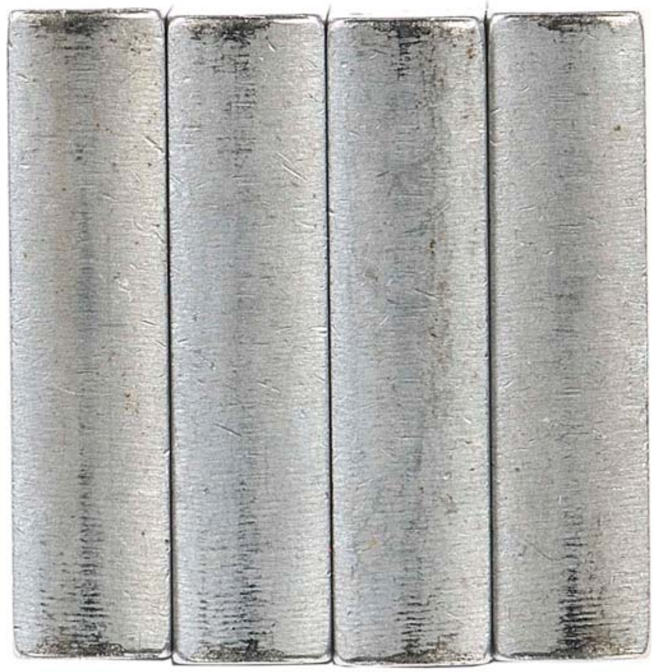


Figure C-39. Pump SN: 15824300 Transfer Pump Blade Edges before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-40. Pump SN: 15824300 Transfer Pump Blade Edges with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-41. Pump SN: 15824300 Transfer Pump Blade Sides before Testing with R8 + 8.5-ppm DCI-4A Fuel

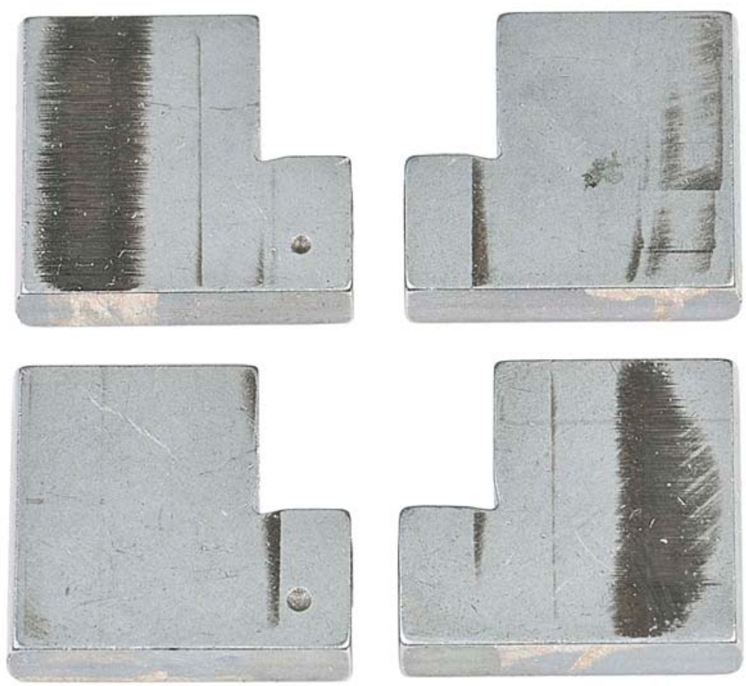


Figure C-42. Pump SN: 15824300 Transfer Pump Blade Sides with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-43. Pump SN: 15824300 Driveshaft Drive Tang before Testing with R8 + 8.5-ppm DCI-4A Fuel

Figure C-44. Pump SN: 15824300 Driveshaft Drive Tang with 500-Hours Testing with R8 + 8.5-ppm DCI-4A Fuel

C6.5.3 R8 Fuel with 2.75-ppm DCI-4A CI/LI Additive – Pump SN: 15824304

The parts conditions and subjective wear ratings for fuel injection pump SN: 15824304 are summarized in Table C-14. Images of the wear seen on the components of fuel injection pump SN: 15824304 are shown in Figure 45 through Figure C-62. Figure C-45 and Figure C-46 show the condition of the injection pump rotor that carries the plungers and distributes the compressed fuel. Figure C-46 shows the discharge ports and rotor are in very good condition after 183-hours.

Figure C-47 and Figure C-48 is the Pre-Test and Post-Test conditions of fuel injection pump SN: 15824304 Roller Shoe and Roller conditions. Of note is the lack of a wear scar at the roller shoe leaf spring contact and the shiny, bright rollers shown in Figure C-47. Figure C-48 reveals substantial wear scars on the roller shoe from the leaf spring contact, and burnishing of the rollers. The rollers tend to discolor when combination rolling-sliding action occurs as the rollers follow the injection cam profile. Figure C-49 and Figure C-50 show the relatively heavy wear scar due to 183-hours operation on the roller shoe plunger contact. The wear seen in Figure C-50 is typical for a poor lubricity fuel. The combination of leaf spring contact wear on the roller shoe, and plunger contact wear on the roller shoe, can result in increased fuel delivery. The injection pump cam ring shown in Figure C-51 and Figure C-52 does reveal some increased polishing on the cam lobes from 183-hours operation with the R8 + 2.75-ppm DCI-4A fuel.

The governor thrust washer condition before and after 500-hours is seen in Figure C-53 and Figure C-54. The light polishing wear seen on the thrust washer in Figure C-54 is due to the shorter 183-hour operating interval. Polishing and light scoring wear seen on the advance piston suggests the fuel pressure fluctuations in that area of the fuel injection pump housing. The metering valve regulates the pressure to the rotor fill ports. The pressure is regulated by the action of the helix changing the outlet area of an orifice. Due to WOT operation a lightly polished area shows at one location on the helix. The light wear on these components is normal considering the 183-hour duration of testing. The wear on the thrust washer, the advance piston wear, and the metering valve did not have an effect on pump operation.

Figure C-55 and Figure C-56 level of wear seen in the transfer pump section of fuel injection pump SN: 15824304. Figure C-55 shows the surface condition of the transfer pump liner prior to testing and Figure C-56 shows the surface with moderate polishing and a circumferential scratch after 183-hours of operation on the R8 + 2.75-ppm DCI-4A fuel. Also illustrative of the transfer pump section wear are the transfer pump blade conditions shown in Figure C-57 through Figure C-60. The edge wear shown in Figure C-57 and Figure C-58 corresponds to the surface on the transfer pump blades that contact the transfer pump liner. The side scuffing shown in Figure C-59 and Figure C-60 reflect wear from the transfer pump blade slots on the injection pump rotor. The wear seen on the transfer pump components is reduced from the neat R8 fuel testing due to the presence of the CI/LI additive in pump SN: 15824304. The pump component wear is greater than seen with the R8 + 8.5-ppm DCI-4A fuel, especially when the reduced hours of operation are considered.

Figure C-61 and Figure C-62 show the condition of the injection pump drive shaft drive tang that transmits torque to the hydraulic section of the pump from the engine. Figure C-62 reveals a slight wear scar, due to the reduced hours of operation.

Table C-14. Pump SN: 15824304 Component Wear Ratings

Stanadyne pump parts Evaluation

Pump Type : DB2831-5209	**SN: 15824304**
Test condition : 183 Hours at Fuel Inlet Temperature 40°C and 1800-RPM WOT	**TEST: R8DCI3-C4UTC2-40-500**

Part Name	Condition of part	Rating 0 = New 5 = Failed
BLADES	Wear at rotor slots and liner contact (standard)	2
BLADE SPRINGS	Rubbing wear	1
LINER	75% scoring wear	3
TRANSFER PUMP REGULATOR	Polishing wear	1
REGULATOR PISTON	Polishing wear	1
ROTOR	Light wear marks at distributor ports	1.5
ROTOR RETAINERS	Wear from rotor contact	1.5
DELIVERY VALVE	Polishing wear (oversized)	1.5
PLUNGERS	Polishing wear	1.5
SHOES	Wear from leaf spring contact, light scuffing from rollers, dimples on backs	3
ROLLERS	Discolored - normal wear	1.5
LEAF SPRING	Heavy wear from shoe contact	4
CAM RING	Wear at roller contact points	1.5
THRUST WASHER	Polishing wear	1.5
THRUST SLEEVE	Normal	1
GOVORNER WEIGHTS	Wear from thrust washer contact	2
LINK HOOK	Dimple on arm at fulcrum pivot point	1.5
METERING VAVLE	Brown deposits, polishing wear	1.5
DRIVE SHAFT TANG	Polishing and light fretting wear	2.5
DRIVE SHAFT SEALS	Normal	1
CAM PIN	Normal, in specification	1
ADVANCE PISTON	Scoring wear	2.5
HOUSING	Normal	1
	AVERAGE DEMERIT RATINGS	1.72

Figure C-45. Pump SN: 15824304 Distributor Rotor before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-46. Pump SN: 15824304 Distributor Rotor with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-47. Pump SN: 15824304 Rollers and Shoe before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-48. Pump SN: 15824304 Rollers and Shoe with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-49. Pump SN: 15824304 Roller Shoe before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-50. Pump SN: 15824304 Roller Shoe with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

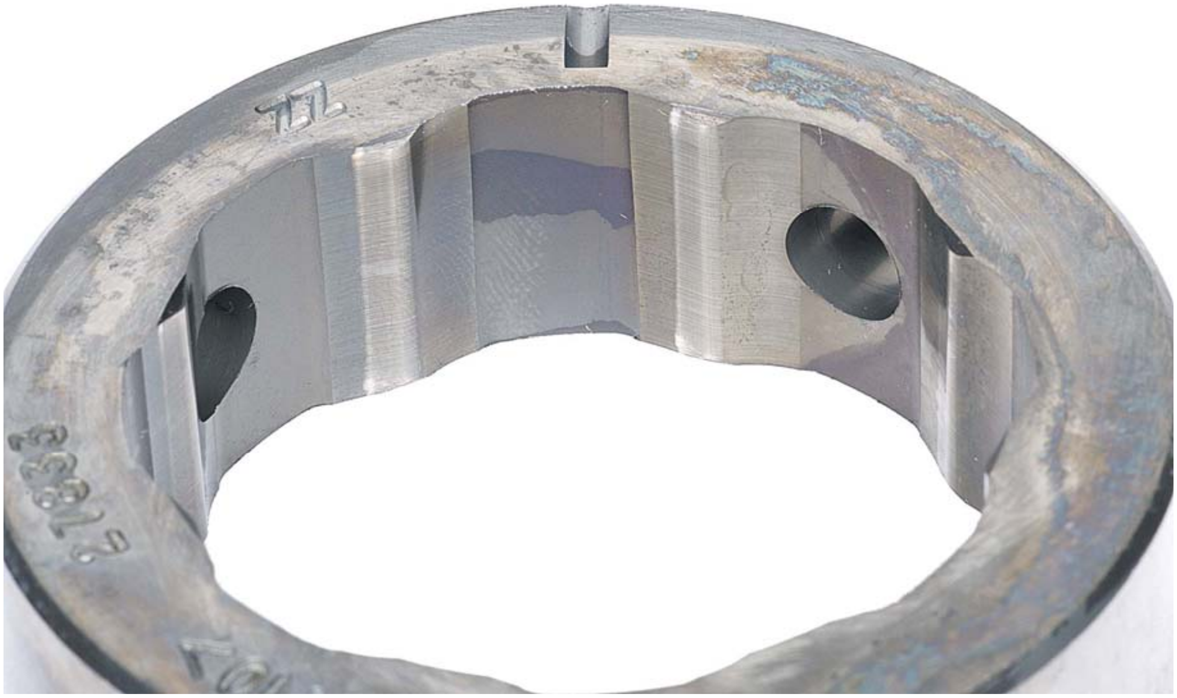


Figure C-51. Pump SN: 15824304 Cam Ring before Testing with R8 + 2.75-ppm DCI-4A Fuel

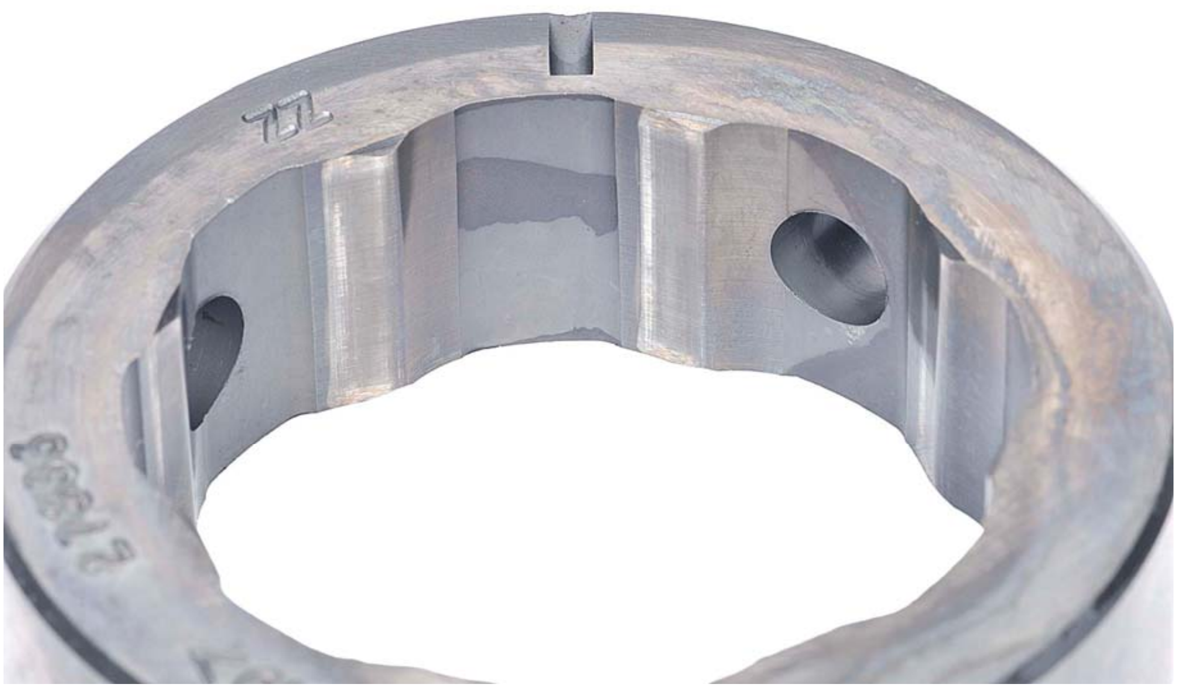


Figure C-52. Pump SN: 15824304 Cam Ring with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-53. Pump SN: 15824304 Thrust Washer before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-54. Pump SN: 15824304 Thrust Washer with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-55. Pump SN: 15824304 Transfer Pump Liner before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-56. Pump SN: 15824304 Transfer Pump Liner with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

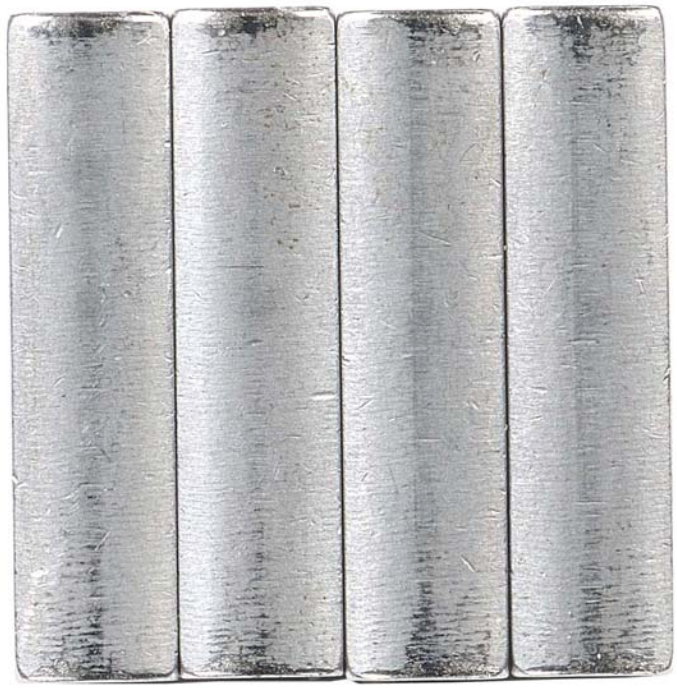


Figure C-57. Pump SN: 15824304 Transfer Pump Blade Edges before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-58. Pump SN: 15824304 Transfer Pump Blade Edges with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-59. Pump SN: 15824304 Transfer Pump Blade Sides before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-60. Pump SN: 15824304 Transfer Pump Blade Sides with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-61. Pump SN: 15824304 Driveshaft Drive Tang Sides before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-62. Pump SN: 15824304 Driveshaft Drive Tang with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

C6.5.4 R8 Fuel with 2.75-ppm DCI-4A CI/LI Additive – Pump SN: 15824313

The parts conditions and subjective wear ratings for fuel injection pump SN: 15824313 are summarized in Table C-15. Images of the wear seen on the components of fuel injection pump SN: 15824313 are shown in Figure C-63 through Figure C-80. Figure C-63 and Figure C-64 show the condition of the injection pump rotor that carries the plungers and distributes the compressed fuel. Figure C-64 shows the discharge ports and rotor with light scratches near the rotor discharge ports, usually from wear debris, after the 183-hours of operation.

Figure C-65 and Figure C-66 is the Pre-Test and Post-Test conditions of fuel injection pump SN: 15824313 Roller Shoe and Roller conditions. Of note is the lack of a wear scar at the roller shoe leaf spring contact and the shiny, bright rollers shown in Figure C-65. Figure C-66 reveals substantial wear scars on the roller shoe from the leaf spring contact; very light burnishing of the rollers, and scratching on the rollers. The rollers tend to discolor when combination rolling-sliding action occurs as the rollers follow the injection cam profile. Figure C-67 and Figure C-68 show the relatively heavy wear scar due to 183-hours operation on the roller shoe plunger contact. The wear seen in Figure C-68 is typical for a poor lubricity fuel. The combination of leaf spring contact wear on the roller shoe, and plunger contact wear on the roller shoe, can result in increased fuel delivery. The injection pump cam ring shown in Figure C-69 and Figure C-70 does reveal some increased polishing on the cam lobes from 183-hours operation with the R8 + 2.75-ppm DCI-4A fuel.

The governor thrust washer condition before and after 500-hours is seen in Figure C-71 and Figure C-72. The polishing wear seen on the thrust washer in Figure C-72 from to the shorter 183-hour operating interval, appears to be similar to 500-hour operation with the R8 + 8.5-ppm DCI-4A fuel. Polishing and light scoring wear seen on the advance piston suggests the fuel pressure fluctuations in that area of the fuel injection pump housing. The metering valve regulates the pressure to the rotor fill ports. The pressure is regulated by the action of the helix changing the outlet area of an orifice. Due to WOT operation a lightly polished area shows at one location on the helix. The light wear on these components is normal considering the 183-hour duration of testing. The wear on the thrust washer, the advance piston wear, and the metering valve did not have an effect on pump operation.

Figure C-73 and Figure C-74 illustrates the level of wear seen in the transfer pump section of fuel injection pump SN: 15824313. Figure C-73 and Figure C-74 shows the surface condition of the transfer pump liner prior to testing and Figure C-74 the surface with moderate polishing and circumferential after 183-hours of operation on the R8 + 2.75-ppm DCI-4A fuel. Also illustrative of the transfer pump section wear are the transfer pump blade conditions shown in Figure C-75 through Figure C-78. The edge wear shown in Figure C-75 and Figure C-76 corresponds to the surface on the transfer pump blades that contact the transfer pump liner. The side scuffing shown in Figure C-77 and Figure C-78 reflect wear from the transfer pump blade slots on the injection pump rotor. The wear seen on the transfer pump components is reduced from the neat R8 fuel testing due to the presence of the CI/LI additive in pump SN: 15824313. The transfer pump blade wear is less than seen with the R8 + 8.5-ppm DCI-4A fuel, due to the reduced hours of operation.

Figure C-79 and Figure C-80 the condition of the injection pump drive shaft drive tang that transmits torque to the hydraulic section of the pump from the engine. Figure C-80 reveals a substantial wear scar considering the reduced hours of operation with the R8 + 2.75-ppm DCI-

4A (0.83-mm BOCLE) test fuel. For both pumps that utilized the R8 + 2.75-ppm DCI-4A (0.83-mm BOCLE) fuel, the significantly worn components that impacted the injection pump performance degradation were the roller shoe leaf spring contact and the roller shoe plunger contact.

Table C-15. Pump SN: 15824313 Component Wear Ratings

Stanadyne pump parts Evaluation

Pump Type : DB2831-5209	**SN: 15824313**
Test condition : 183 Hours at Fuel Inlet Temperature 40°C and 1800-RPM WOT	**TEST: R8DCI3-C4UTC2-40-500**

Part Name	Condition of part	Rating 0 = New 5 = Failed
BLADES	Wear at rotor slots and liner contact (standard)	2
BLADE SPRINGS	Rubbing wear	2
LINER	70% polishing and light scuffing wear	2.5
TRANSFER PUMP REGULATOR	Wear mark from rotor contact, light polishing	1.5
REGULATOR PISTON	Brown deposits and polishing wear	2
ROTOR	Radial wear marks at distributor port	3
ROTOR RETAINERS	Polishing and rubbing wear from rotor contact	2.5
DELIVERY VALVE	Scuffing and polishing wear	3
PLUNGERS	Polishing wear	1.5
SHOES	Light roller scuffing, heavy wear from leaf spring contact, shoe back dimples	4
ROLLERS	Radial scuffing lines and marks	2.5
LEAF SPRING	Heavy wear from shoe contact	4
CAM RING	Polishing wear	1
THRUST WASHER	Polishing wear	1.5
THRUST SLEEVE	Wear from governor arm fingers, brown stains, wear from governor weights	2
GOVORNER WEIGHTS	Brown stains and deposits, wear from thrust washer contact	1.5
LINK HOOK	Dimple from governor rod at pivot point on arm	2
METERING VAVLE	Polishing wear	1.5
DRIVE SHAFT TANG	Polishing and fretting wear	2.5
DRIVE SHAFT SEALS	Normal	1
CAM PIN	Normal, in specification	1
ADVANCE PISTON	Scoring wear	3
HOUSING	Light brown stains	1
	AVERAGE DEMERIT RATINGS	2.11

Figure C-63. Pump SN: 15824313 Distributor Rotor before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-64. Pump SN: 15824313 Distributor Rotor with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-65. Pump SN: 15824313 Rollers and Shoe before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-66. Pump SN: 15824313 Rollers and Shoe with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-67. Pump SN: 15824313 Roller Shoe before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-68. Pump SN: 15824313 Roller Shoe with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-69. Pump SN: 15824313 Cam Ring before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-70. Pump SN: 15824313 Cam Ring with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-71. Pump SN: 15824313 Thrust Washer before Testing with R8 + 2.75-ppm DCI-4A Fuel

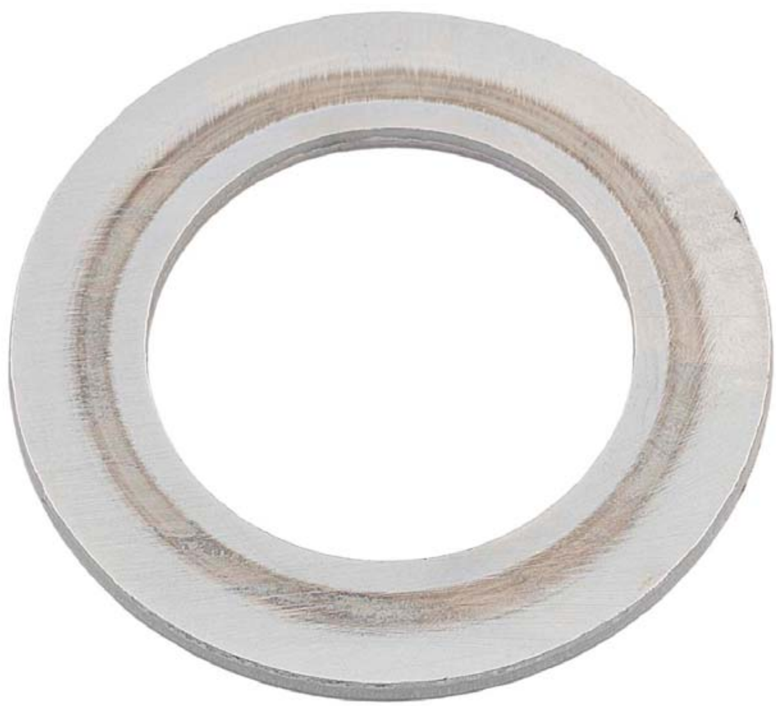


Figure C-72. Pump SN: 15824313 Thrust Washer with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-73. Pump SN: 15824313 Transfer Pump Liner before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-74. Pump SN: 15824313 Transfer Pump Liner with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-75. Pump SN: 15824313 Transfer Pump Blade Edges before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-76. Pump SN: 15824313 Transfer Pump Blade Edges with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-77. Pump SN: 15824313 Transfer Pump Blade Sides before Testing with R8 + 2.75-ppm DCI-4A Fuel

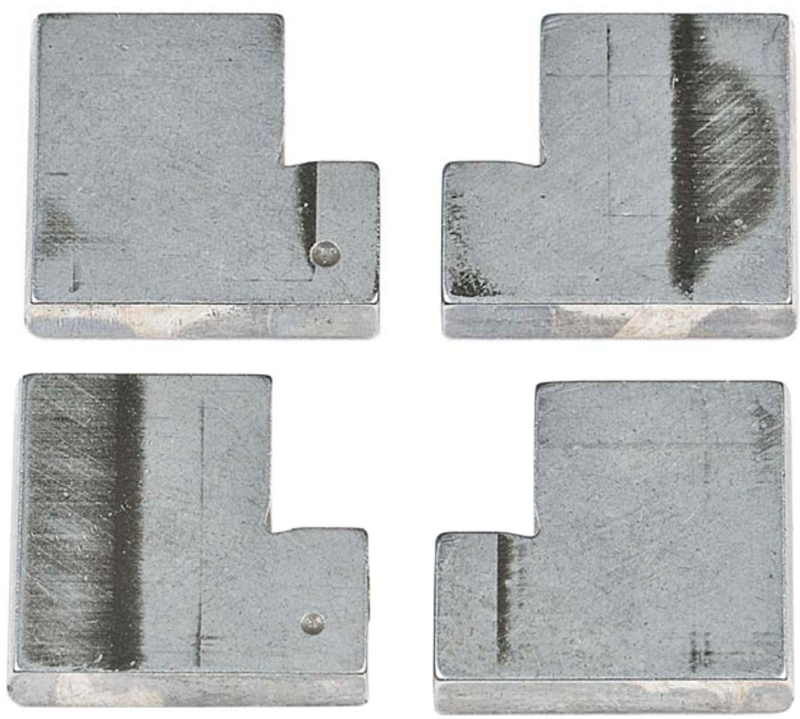


Figure C-78. Pump SN: 15824313 Transfer Pump Blade Sides with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-79. Pump SN: 15824313 Driveshaft Drive Tang before Testing with R8 + 2.75-ppm DCI-4A Fuel

Figure C-80. Pump SN: 15824313 Driveshaft Drive Tang with 183-Hours Testing with R8 + 2.75-ppm DCI-4A Fuel

C7.0 DISCUSSION OF RESULTS

In a previous study (1) the effect of synthetic R8 on the durability of the Stanadyne arctic rotary fuel injection pump that contains hardened parts was examined. This fuel injection pump is found on the HMMWV. In conducting the R8 pump stand test, it was found that the tests had to be stopped prematurely for the following reasons:

- Excessive Fuel Delivery
- Wear debris was observed
- Increased Transfer pump pressure

The most frequent out of specification parameters during the post-test pump performance checks were:

- Change of Injection Timing
- Increased fuel flow at various speeds

For a results comparison to the R8 fuel, a prior test program performed on a synthetic kerosene grade S-5 was reviewed. (2) The comparison of the R8 and S-5 fuels performance in rotary fuel injection pumps discussed in the previous report (1) suggested that both fuels (R8 and S-5) when utilized neat resulted in premature component wear. On a positive note, reference 2 also performed tests with CI/LI additives in S-5 fuel that showed a substantial improvement if rotary fuel injection pump durability with synthetic fuel.

Another study (3) was performed to determine the impacts of a QPL-25017 CI/LI additive on fuel injection pump durability with R8 fuel. The CI/LI additive DCI-4A was used at a 22.5-ppm concentration in R8 fuel and in a 50/50-percent blend of R8/Jet-A fuel. In conducting the pump stand tests with the two fuels, it was found that the both tests had completed 500-hours of operation with the following observations:

- Minor Fuel Delivery loss at Rated speed
- Small Fuel delivery loss at Idle speed
- Wear debris minimal
- No unusual deposits
- Polishing to light scuffing wear seen on components; wear normal for 500-hours operation
- Rotary Fuel injection pumps functioning normally at 500-hours

The most frequent out of specification parameters of the study (3) during the post-test pump and fuel injector performance checks were:

- Tip dryness, seat sealing, of fuel injectors with R8/Jet-A fuel blend
- Decreased fuel flow at Idle and Rated speeds

The current study was performed to determine the impact of minimal QPL-25017 CI/LI additive levels on fuel injection pump durability with R8 fuel. The minimal additive levels were determined by the additive concentration that resulted in an ASTM D5001 BOCLE wear scar

targets of 0.75-mm and 0.85mm. The resulting test fuels were R8 + 8.5-ppm DCI-4A with a 0.75-mm BOCLE wear scar, and R8 + 2.75-ppm DCI-4A with a 0.83-mm BOCLE wear scar.

Although the 0.75-mm BOCLE wear scar R8 fuel completed 500-hours of operation there was performance degradation of the fuel injection pumps, such that:

- Engine peak torque would be decreased
- Engine peak power would be decreased
- Cranking speed delivery at zero, engine would be unable to start

The 0.83-mm BOCLE wear scar R8 fuel completed only 183-hours of operation due to substantial over fuelling by the fuel injection pumps, such that:

- Exhaust black smoke would increase at all conditions
- Cranking speed delivery increase would cause white smoke, possibly too rich to ignite
- Half of the fuel injectors exhibited performance degradation that would impact engine operation and emissions

Compared to the neat R8, the 0.75-mm and 0.83-mm BOCLE R8 fuels had less wear, and substantially less fuel deposition.

C8.0 CONCLUSIONS

The following conclusions can be made from the cumulative knowledge of utilizing synthetic R8 HRJ fuel in diesel rotary fuel injection pumps:

1. In conducting the R8 fuel blends pump stand tests, it was found that the tests could be operated to conclusion at 500-hours:
   - R8 fuel with 8.5-ppm DCI-4A CI/LI additive
   - R8 fuel with 22.5-ppm DCI-4A CI/LI additive
   - R8/Jet-A fuel blend with 22.5-ppm DCI-4A CI/LI additive
   - Light component wear
   - Substantial durability increase over neat R8 fuel
2. The most frequent out of specification parameters during the post-test pump and fuel injector performance checks were:
   - Tip dryness, seat sealing, of fuel injectors with R8/Jet-A fuel blend
   - Decreased fuel flow at Idle and Rated speeds
3. Unusual heavy, brown deposition not present with either CI/LI treated R8 fuel.
4. R8 fuel with 22.5-ppm DCI-4A CI/LI additive was slightly more erratic in fuel delivery throughout the 500-hour test.
5. R8/Jet-A fuel blend with 22.5-ppm DCI-4A CI/LI additive had slightly less component wear, and slightly better 500-hour delivery performance.
6. R8 fuel with 8.5-ppm DCI-4A CI/LI additive caused decreased fuel delivery throughout the 500-hour test, impacted engine starting ability, and would not be recommended for diesel engine use.
7. R8 fuel with 2.75-ppm DCI-4A CI/LI additive is ineffectual in providing proper diesel engine rotary fuel injection pump wear protection.

C9.0 RECOMMENDATIONS

The technical feasibility of using R8 fuel in rotary fuel injection equipment when blended with a CI/LI additive and petroleum based commercial aviation kerosene has been investigated:

1. It is recommended the blend of R8 and Jet-A fuels, with the addition of 22.5-ppm DCI-4A CI/LI, can be used in diesel rotary fuel injection equipment with minor durability impact and minor performance degradation.
2. It is recommended that other CI/LI additives and additive treatment levels below the QPL-25017 minimum effective concentration not be utilized with R8 fuel.

C10.0 REFERENCES

1. Final Report for Southwest Research Institute® Project No. 08.13283.01.001, "*Research of Renewable IPK Alternative Jet Fuel",* G.R. Wilson III*,* December 19, 2008.
2. "Synthetic Fuel Lubricity Evaluations", Interim Report TFLRF No. 367, E.A. Frame and R.A. Alvarez, U.S. Army TARDEC Fuels and Lubricants Research Facility (SwRI), Southwest Research Institute, September 2003, ADA 421822.
3. Final Report for Southwest Research Institute® Project No. 08.14406.03,*"R8 Rotary Fuel Injection Pump Wear Testing",* G.R. Wilson III, and D. Yost, January 2010, ADA 560574.

APPENDIX D

EVALUATION OF JP-8 AT HIGH TEMPERATURE IN THE FORD 6.7L HIGH PRESSURE COMMON RAIL DIESEL ENGINE

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Approved for public release, distribution unlimited.

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D1.0 EXECUTIVE SUMMARY

Commercial Off-The-Shelf (COTS) diesel engines are available to the U.S. Military that employ High Pressure Common Rail (HPCR) fuel injection systems. Use of aviation jet fuel in addition to diesel fuel in these diesel engines is being required to provide maximum flexibility in the battlefield as part of the Single Fuel Forward policy. Overall performance and endurance of these HPCR systems has the potential to vary with use of military or alternative fuels due to critical chemical and physical property differences compared to standard diesel fuels. Diesel engines are required to meet military automotive performance utilizing aviation jet fuels without fuelling or timing adjustments. Of the critical property differences of military fuels, changes in fuel viscosity and lubricity are of particular interest. Many modern HPCR systems utilize fuel lubricated high pressure pumps, and can generate upwards of 2000 bar fuel rail pressures placing large demands on the fuel to adequately lubricate and protect internal components.

To understand critical fuel related impacts, performance and endurance testing was conducted using a fired engine equipped with a modern fuel lubricated HPCR fuel system using JP-8 at elevated inlet temperatures (70°C, maximum specified fuel system temperature, versus 32°C for conventional testing) treated with 9 ppm of a QPL-25017 additive that resulted in a 0.58 mm BOCLE wear scar diameter. Testing was completed using a Ford 6.7L V8 turbocharged diesel engine. The engine used was tested in its "export" configuration, which does not utilize Exhaust Gas Recirculation (EGR) or exhaust after-treatment systems. Testing was completed following a modified version of the U.S. Army 210-hr Tactical Wheeled Vehicle Cycle (TWVC).

At the completion of testing, the fuel injection pump and injectors were removed and disassembled for inspection and comparison. Component inspections for the elevated temperature JP-8 test were compared to component conditions from previous work performed for the U.S. Army and U.S. Air Force (3, 4). Engine power curves and emissions were taken at the start and end of testing, and used to document any engine performance degradation incurred over the test duration.

The engine fueled with elevated temperature JP-8 was successfully operated over the entire test duration without experiencing any unusual fuel-related operational conditions or hardware failures. At the minimum lubricity enhancing treat rate, the tested JP-8 fuel provided adequate component protection and system performance despite being operated at the maximum specified diesel fuel inlet temperature of the system. Post-test fuel injection system inspection found tested components to be in similar condition compared to all previous fuels tested. Results from testing support the durability of the fuel lubricated HPCR fuel system utilized on the Ford 6.7L with a military specified JP-8 fuel at elevated temperatures.

D2.0 INTRODUCTION

A large number of current Commercial Off-The-Shelf (COTS) diesel engines available to the U.S. Military employ High Pressure Common Rail (HPCR) fuel injection systems. Life cycle performance and endurance of these HPCR fuel systems have the potential to be impacted by critical chemical and physical property differences between military specification fuels and standard diesel fuels. Although these critical factors can include many different properties, primary concerns lie with the fuel's lubricity and viscosity, as these can have major impacts on fuel system hardware durability. With the large in-flux of HPCR technology into the diesel engine market, questions have arisen on whether these modern HPCR systems can maintain adequate performance and durability using military fuels in extreme operating conditions.

D2.1 Objective

The test objective was to determine the performance and endurance of a modern high pressure common rail diesel fuel injection system when operated on JP-8 at high inlet temperatures, consistent with conditions that might be expected during desert warfare use. This test was an additional test completed to complement previous testing under Project 08.16246.03, in which a high pressure common rail diesel fuel system was evaluated using a 50/50 blend of Hydroprocessed Renewable Jet (HR-J) and JP-8. Similar to previous evaluations, testing was completed following a modified version of the 210-hour Tactical Wheeled Vehicle Cycle engine endurance test cycle (CRC Report No. 406, Development of Military Fuel/Lubricant/Engine Compatibility Test) (1). Evaluations of performance and durability included, but were not limited to, fuel system hardware interactions, engine performance changes, and engine out emissions evaluations. This work was completed in support of Project 08.16246, Advanced Propulsion Fuels Research and Development.

D3.0 RESULTS AND DISCUSSIONS

Consistent with previous testing, the Ford 6.7L diesel engine was utilized as a representative engine equipped with a modern high pressure common rail fuel injection system. The Ford 6.7L engine is a V8, direct-injected, turbo-charged, intercooled engine, which employs a fuel-lubricated high-pressure common rail injection pump and piezo-electric fuel injectors. The 6.7L engine used for testing was the same engine used during the 50/50 HRJ/JP-8 evaluation, and was produced by Ford as an "export" version intended for sale outside of U.S borders or to military forces. In the export configuration, the engine is not equipped with an engine exhaust after-treatment system or exhaust gas recirculation (EGR) system. The 6.7L export version engine is rated at approximately 320hp (238kW) at 2800 rpm, and produces approximately 700 lb-ft (950 N-m) of torque at 1800 rpm when using diesel fuel. Figure D-1 below shows the 6.7L engine test installation. Since the test engine had been previously used under Project 16246.03, it was fitted with all new fuel system hardware to bring it to "as-new" condition prior to testing.

Figure D-1. Ford 6.7L Engine Test Stand Installation

D3.2 Fuel System Description

The fuel injection system on the Ford 6.7L engine utilizes a fuel-lubricated high-pressure pump supplying two pressure-controlled fuel rails and 8 piezo-electric-actuated fuel injectors. The Fuel Injection Pump (FIP) is mounted at the front of the engine valley and gear driven at 1:1 engine speed. The FIP is a two cylinder design and utilizes a two lobe cam to provide four pulses per revolution. The FIP is timed to the crankshaft and camshaft orientation to optimize pressure pulses within the fuel system during operation. Fuel management is controlled by the Powertrain Control Module (PCM) through the use of a FIP mounted Volume Control Valve (VCV) and a fuel rail mounted Pressure Control Valve (PCV). The engine primarily operates in VCV mode, in which the VCV valve regulates the amount of fuel entering the high pressure portion of the FIP

based on engine demands. The PCV allows the PCM to trim the fuel rail pressure as needed, to regulate total fuel rail pressure and adjust as engine demands change. This design is primarily utilized to increase the efficiency of the fuel injection system, as only the fuel required for operation is compressed by the pump and sent to the fuel rails. Figure D-2 below shows the Ford 6.7L fuel injection pump, fuel pressure rail, and fuel injector. The VCV is located atop the center of the FIP between the two high pressure cylinder head assemblies. The PCV valve is located at the left end of the high pressure fuel rail as seen below.

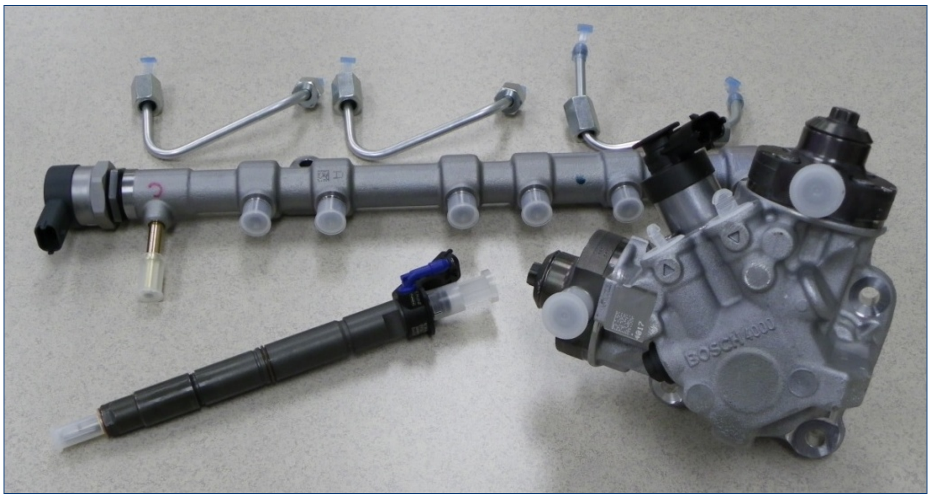


Figure D-2. Ford 6.7L Fuel Injection Pump, Rail, & Injector

The high pressure portion of the FIP consists of a high pressure plunger and barrel assembly that is actuated by roller follower assembly driven from the FIP camshaft. Regulated fuel from the VCV valve is drawn into the barrel assembly on the downward stroke, and then compressed and brought to the specified rail pressure upon plunger ascent. High pressure fuel exits the barrel assembly through a spring loaded check ball into high pressure fuel lines that supply the fuel rails. Figure D-3 below shows the orientation of high pressure pumping assembly. Critical wear points for these components can include: roller and shoe surface wear, scuffing on the follower and follower bore surfaces, plunger and barrel surface wear and scuffing, wear between high pressure plunger head and shoe assembly, as well as fuel check valve and seat wear.

Figure D-3. Camshaft Follower & High Pressure Plunger & Barrel Assy

Figure D-4 shows a parts break-out of the fuel injector. The fuel injector is a piezo-electric actuated unit that acts against one piston (upper) of a hydraulic coupler (Figure D-5) that is filled with fuel from the low pressure lift pump portion of the fuel system. The hydraulic coupler translates the small linear movement of the piezo-stack to a larger movement by the difference in piston diameters within the hydraulic coupler. The second piston (lower) of the hydraulic coupler acts against the injector control valve (Figure D-6) that regulates the pressure on the top of the injector needle controlling the needle lift. When the control valve is forced down, the high pressure fuel passage is blocked lowering the pressure acting on the top of the needle and allowing the high pressure fuel acting below to lift the needle and inject fuel into the combustion chamber. Figure D-5 and Figure D-6 show larger views of the hydraulic coupler and control valve assembly. Critical wear points for these components can include: control valve and seat wear, wear and scuffing on needle surface from guide, needle seat wear, and deposit formation on nozzle.

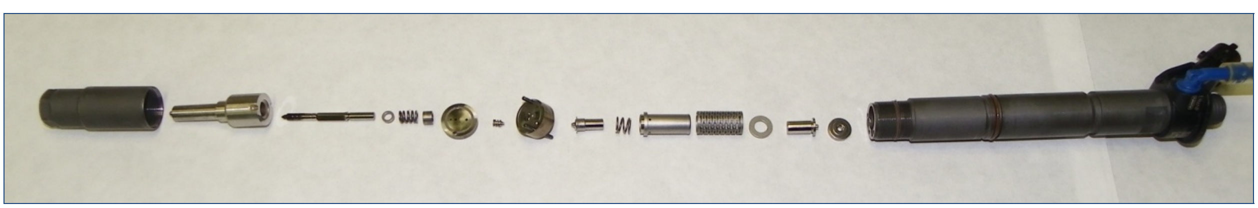


Figure D-4. Fuel Injector Component Break-out

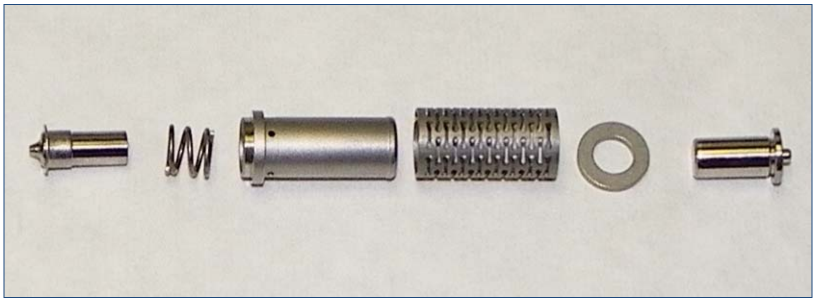


Figure D-5. Fuel Injector Hydraulic Coupler

Figure D-6. Fuel Injector Control Valve Assembly

D3.3 Test Stand Configuration

The engine was mounted in a test stand specifically configured for Ford 6.7L engine testing. The following list outlines the general test stand set-up in regards to the engine installation, and ancillary equipment used during testing:

- The engine was fully instrumented to monitor various engine parameters, temperatures, and pressures throughout testing. A SwRI developed data acquisition and controls system (PRISM) was used to display and log real time engine data during testing.
- Engine speed was controlled by an absorption eddy current dynamometer. Engine load was controlled using a PRISM controller and actuator to manipulate the drive-by-wire throttle pedal attached to the engine's dynamometer harness.
- Coolant temperature (engine water jacket and secondary coolant loop) was controlled by PRISM using the building supplied process water and appropriately sized heat exchangers in place of the engines radiators.
- The engine was supplied with fuel by using a "day tank" at ambient temperature (not 70°C) and pressure conditions. The day tank temperature was maintained at ambient conditions throughout testing to ensure the contained volume remained below the fuels flash point for safety concerns. The day tank is used to allow the engine to feed and return fuel as required during operation, while allowing the measurement of the makeup fuel required for maintaining a constant fuel level to quantify overall engine fuel

consumption. Make up fuel flow rate was measured using a Micro Motion Coriolis flow meter and logged with PRISM throughout testing.

- Fuel from the day tank was supplied to the engines diesel fuel condition module (DFCM) at the elevated 70°C test temperature. The pre-heating of the fuel was accomplished by using an external fuel coolant loop maintained at elevated temperatures by resistance type circulation heaters. This external fuel coolant loop provided a consistent heat source in which the inlet fuel temperature was elevated with the use of liquid-liquid heat exchangers. Prior to the engine, the fuel received final heating through an additional liquid-liquid heat exchanger that was provided elevated temperature coolant from the engines water jacket. These two systems combined allowed the fuel to be raised from ambient temperature to the specified 70°C inlet temperature prior to the DFCM which houses the primary fuel filter and low pressure lift pump for the engine. On the return side of the engine, the DFCM contains a temperature controlled recirculation device that re-routes engine return fuel to the engine supply until a desired fuel temperature is met. At the elevated fuel inlet temperature tested, the DFCM was expected to constantly return all return fuel back to the day tank effectively defeating the recirculation device. After exiting the DFCM, the return fuel was cooled through an additional liquid-liquid heat exchanger and the building process water to ensure the day tank temperature remained below the fuels flash point.
- Inlet air was drawn in at ambient conditions from the test cell through a radiator core into the engine air box. The radiator core is supplied building process water to prevent extreme heat buildup in the test cell from elevating inlet air temperatures.
- Engine exhaust is drawn from the engine by the buildings exhaust handling system and discharged outside to the atmosphere. A butterfly valve was used to regulate engine exhaust backpressure to the Ford recommended 11 psi specification.
- Emissions were directly sampled from an exhaust probe installed between the engine and exhaust system backpressure valve. Emissions were measured using a Horiba MEXA-1600D Motor Exhaust Gas Analyzer. Exhaust sample handling was carried out by the Horiba systems heated filter and line routed into the emission bench sample conditioning unit.
- Crankcase blow-by gasses were recirculated into the turbo compressor inlet via the factory blow-by control devices.
- The engine was lubricated with commercially available full synthetic CJ-4 SAE 5W-40 engine oil per Ford specifications for heavy duty applications.
- Used oil samples were collected from the engine daily to monitor engine and oil condition, and to determine oil change intervals needed during testing.

D3.3 Engine Run-in

Prior to testing, the engine was run-in following the Ford specified engine run-in procedure. Table D-1 below, outlines the Ford recommended engine run-in procedure.

Table D-1. Ford Recommended Run-In Procedure

Step	Duration	Speed [rpm]	Load [lb-ft]	Load [N-m]
1	0:05	650	0	
2	0:30	1000	72	97
3	0:30	1200	103	140
4	0:30	1400	141	191
5	0:30	1500	162	219
6	0:30	1600	184	249
7	0:30	1700	208	282
8	0:30	1800	233	316
9	0:30	2000	287	390
10	0:30	2200	348	472
11	0:30	2400	414	561
12	0:30	2500	449	609
13	0:30	2600	486	659
14	0:30	2700	524	710
15	0:30	2800	563	764

D3.5 Pre and Post Test Engine Performance Checks

Before and after testing, engine power curves were completed at varying speeds and loads to determine pre-test engine performance. Engine performance was documented at engine speeds of 1400, 1800, 2200, 2400, and 2800 rpm, with load intervals of 25%, 50%, 75%, and 100% of full load. Power curves were completed at both ambient (95°F) and desert condition (120°F) inlet fuel temperatures. Exhaust gas emissions were sampled at each point on the curve to document engine out emissions. Power curve plots can be seen in the Engine Performance Curves section.

D3.6 Test Cycle

The test cycle followed during fuel system evaluation was a modified version of the 210-hr Tactical Wheeled Vehicle cycle as outlined in CRC Report No. 406, Development of Military Fuel/Lubricant/Engine Compatibility Test. Modifications were made to the outlined test cycle to accelerate the overall testing schedule, resulting in daily runtime of 21-hrs (15-hr at rated speed/load, 6 hrs idle) followed by a 3-hr engine off soak. The modified daily cycle was arranged in a manner to preserve the total number of rated and idle hours over the entire test duration consistent with the standard cycle. The modified daily cycle consisted of 6 repeating segments of 2-hr 10 min at rated speed/load followed by a 1 hr idle step. At the completion of the 6 cycles, the engine completed a final 2 hr rated step, and then entered the engine off soak period. Throughout testing engine coolant temperatures were maintained at Ford specifications to ensure engine integrity. Engine coolant utilized was a 50/50 blend of ethylene glycol antifreeze and deionized water. Engine operating parameters were controlled as specified in Table D-2 below. These operating parameters were based on Ford’s recommended specifications, except for the fuel inlet temperature which was maintained at the maximum specified fuel inlet temperature of the HPCR fuel injection system (70°C/158°F).

Table D-2. Test Cycle Operation Parameters

Parameter	Rated Speed	Idle
Engine Speed	2800 rpm +/-25	NC
High Temp Coolant Loop	203°F +/- 3	NC
Low Temp Coolant Loop	100°F +/- 3	NC
Oil Sump Temperature	NC	NC
Inlet Manifold Temperature	105°F +/- 3	NC
Fuel Inlet Temperature	158°F +/-3	158°F +/-3
*NC = not controlled		

(Note – Engine idle speed was controlled by PCM at approximately 600 rpm (i.e. no throttle input). Temperature controllers remained at rated speed set points for idle conditions, but were allowed to reach their natural steady state value during idle testing steps. Engine oil cooler plumbing was integral to the engine water jacket, thus not directly controlled in either idle or rated steps. Oil temperatures were allowed to meet their own steady state temperature based on water jacket temperature and engine load/speed throughout testing.)

D3.7 Oil Sampling

Four ounces of engine oil was sampled every 21-hours (daily) for used oil analysis. Used oil analysis consisted of the following tests as seen in Table D-3 on the following page. Engine oil changes were to be performed on the engine based on used oil condition. In this case the lubricant did not require a change during the 210-hour cycle. Engine oil level was checked daily, and replenished as needed to restore oil level to full mark. This process occurred after the completion of the 3-hour soak prior to restarting testing the next day. Used oil analysis results can be seen in the engine oil analysis and engine oil analysis trends section of the report.

Table D-3. Used Oil Analysis Procedures

Daily Used Oil Analysis		
ASTM	**D4739**	Total Base Number
ASTM	**D664**	Total Acid Number
ASTM	**D445**	Kinematic Viscosity @ 100°C
ASTM	**D4052**	Density
ASTM	**TGA SOOT**	TGA Soot
ASTM	**E168**	Oxidation
ASTM	**E168**	Nitration
ASTM	**D5185**	Wear Metals by ICP

D3.8 Test Fuel

The test fuel used was JP-8 blended at location from commercially available Jet-A. JP-8 is typically made by blending military additives into Jet-A-1 which has a lower freeze point specification than Jet-A. Since the primary focus of testing was fuel lubricity compatibility, only the lubricity enhancer/corrosion inhibitor additive was blended into the Jet-A. The remaining two additives typically found in JP-8 have little impact on fuel lubricity levels and fuel system durability. The lubricity enhancer used was Innospec Fuel Specialties DCI-4A. Per QPL-25017, the minimum effective treat rate of DCI-4A required an additive concentration of 9 ppm in the

final fuel blend. In an effort to determine fuel system impact in a “worst case” scenario, the test fuel was treated only at the minimum effective treat rate regardless of the resulting lubricity level achieved. After the test fuel was additized and blended, fuel samples were collected to determine critical chemical and physical properties of the fuel for reporting. Table D-4 summarizes the critical properties of the tested JP-8, designated AF-8029.

Table D-4. Test Fuel AF-8029 Chemical & Physical Analysis

Property	Units	Method	Results
Density @15°C	g/mL	D4052	0.7835
Specific Gravity @15°C		D4052	0.7843
API Gravity @15°C		D4052	48.9
Flashpoint	°F	D56	113
	°C	D93	44.5
	°C	D3828	45
Freeze Point	°C	D2386	-45.4
Kinematic Viscosity @ -20°C	cSt	D341	3.90
Kinematic Viscosity @ 20°C	cSt	D445	1.70
Kinematic Viscosity @ 40°C	cSt	D445	1.27
Hydrocarbon Content			
Carbon	wt%	D5291	85.45
Hydrogen	wt%		14.3
Calculated Cetane Index	CCI	D976	51.7
Calculated Cetane Index, Four Variable	CCI	D4737	54.5
Cetane Number	CN	D613	52.9
Ignition Quality Tester™	DCN	D6890-04	51.0
Heat of Combustion (Gross)	BTU/lb	D240	19883.9
Total Acid Number	mg KOH/g	D3242	0.008
Hydrocarbon Type			
Aromatics	%mass	D5186	13.9
Hydrocarbon Type			
Aromatics	%vol	D1319	11
Olefins			0.8
Saturates			88.2
Sulfur	ppm	D5453	40
Nitrogen	wt%	D3228	<0.030
HFRR	mm	D6079	0.613
BOCLE	mm	D5001	0.58
Bulk Modulus @30°C	psi	by Speed of Sound	178047
Distillation			
IBP	°C	D86	156.1
10%			174.5
20%			181.8
50%			200.9
90%			240.8
End Pt			265.6

D4.0 Endurance Test Cycle Results

The following information summarizes the results of the engine fuel system endurance tests. Data includes: engine operating summary, power curve analysis, engine out emissions, used oil analysis, post test component inspection, post test component photos, and listing of any problem areas or anomalies experienced during testing.

D4.1 Engine Operating Conditions Summary

Table D-5 is a summary of the engine operating conditions averaged over the test duration.

Table D-5. Engine Operating Condition Summary

		Rated Conditions (2800 RPM)		Idle Conditions (600 RPM)	
Perameter:	**Units:**	**Average**	**Std. Dev.**	**Average**	**Std. Dev.**
Engine Speed	RPM	2800.0	2.02	596.6	3.69
Torque*	ft*lb	588.4	11.63	35.1	3.80
Fuel Flow	lb/hr	128.0	2.57	1.8	0.66
Power*	bhp	313.7	6.21	4.0	0.43
BSFC*	lb/bhp*hr	0.408	0.01	0.485	1.11
Temperatures:					
High Temperature Loop Coolant In	°F	185.1	0.78	174.8	9.44
High Temperature Loop Coolant Out	°F	203.0	0.61	177.8	9.76
Low Temperature Loop Coolant In	°F	100.0	1.26	92.0	5.55
Low Temperature Loop Coolant Out	°F	132.5	1.58	91.9	5.50
Oil Sump	°F	234.9	1.11	182.1	10.20
Fuel In	°F	157.8	1.97	154.2	3.13
Fuel Pump Drain	°F	165.3	4.31	150.9	3.54
Fuel Return	°F	99.9	16.56	98.6	7.15
Intake Air Before Compressor	°F	76.3	2.29	77.6	3.10
Intake Air After Compressor	°F	335.8	5.49	92.3	4.95
Intake Air After Charge Cooler	°F	105.9	1.23	91.7	5.66
Cylinder 1 Exhaust	°F	1398.9	17.92	262.8	16.76
Cylinder 2 Exhaust	°F	1362.4	19.28	266.1	13.92
Cylinder 3 Exhaust	°F	1413.1	19.87	276.5	13.10
Cylinder 4 Exhaust	°F	1426.4	21.93	265.6	13.14
Cylinder 5 Exhaust	°F	1400.0	17.00	265.7	15.39
Cylinder 6 Exhaust	°F	1427.2	16.89	279.5	14.47
Cylinder 7 Exhaust	°F	1430.3	17.94	271.2	13.88
Cylinder 8 Exhaust	°F	1407.0	19.34	270.4	13.56
Exhaust After Turbo	°F	1165.7	18.81	224.5	16.22
Pressures:					
Oil Galley	psi	57.3	0.38	29.0	1.96
Ambient Pressure	psiA	14.3	0.16	14.3	0.19
Intake Restriction	psi	0.5	0.14	0.0	0.16
Exhaust Restriction	psi	10.4	0.23	-0.1	0.05
Boost Pressure	psi	19.2	0.56	0.4	0.17
Fuel Rail Pressure	psi	19394.1	54.36	3980.6	36.12

* Non-corrected Values

D4.2 Engine Performance Curves

The plots below show the pre and post test engine power curves. Figure D-7 reveals the pre, and post test composite full load power curve for both fuel inlet temperatures of 95°F and 120°F. After 210-hours of operation using elevated temperature JP-8, the engine max power had decreased by 3.0% at ambient fuel temperature and 1.9% at the elevated 120°F fuel temperature.

Included in Table D-6 are the power reductions seen due to durability testing of the engine on ULSD and JP-8 at 90°F (32°C) and JP-8 at 158°F (70°C) for 210-hours. Operation with JP-8 at elevated fuel inlet temperature did not result in power reductions any worse than seen with operation with JP-8 at nominal "Ambient" fuel temperature.

Table D-6. Comparison of Ford 6.7 L Power Reduction with Test Fuel and Test Fuel Temperature

Fuel	Durability Test Fuel Temperature, °F (°C)	Test Duration, Hours	Power Curve Fuel Temperature, °F	Power Reduction after Test Duration, %
nbULSD	90 (32)	210	95	1.8
			120	1.9
JP-8	90 (32)	210	95	2.6
			120	3.0
JP-8	158 (70)	210	95	3.0
			120	1.9

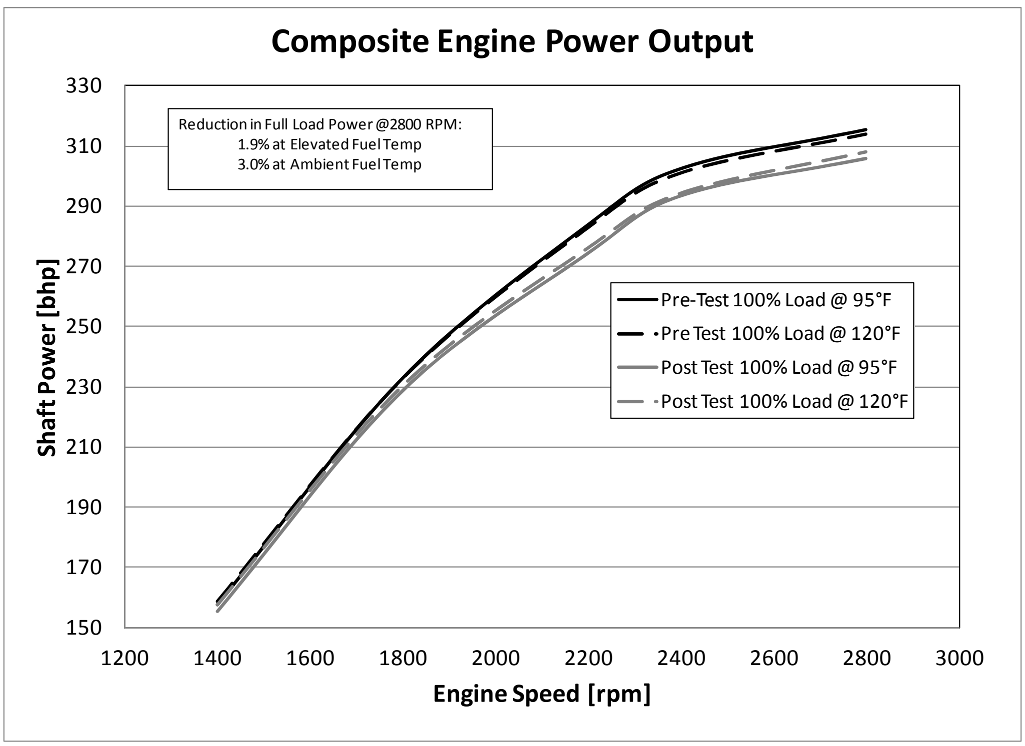


Figure D-7. Composite Engine Power Output

Figure D-8 shows a composite of the Full Power curves for the two fuel temperatures, for both of the JP-8 test runs in a Ford 6.7 L engine. It should be noted two different engines were utilized for testing with JP-8 at ambient fuel inlet conditions and JP-8 at elevated fuel inlet temperature.

The power curves are remarkably consistent for the two engines, at both temperatures and after the durability testing.

Figure D-9, and Figure D-11 show the engine power output performance maps generated with JP-8 fuel at the pre, and post test intervals respectively, for the 25%, 50%, 75%, and 100% pedal positions. Exhaust emission data was taken at each one of the speed/load points on the maps. Figure D-10, and Figure D-12 show the engine torque output performance maps generated with JP-8 fuel at the pre, and post test intervals respectively, for the 25%, 50%, 75%, and 100% pedal positions.

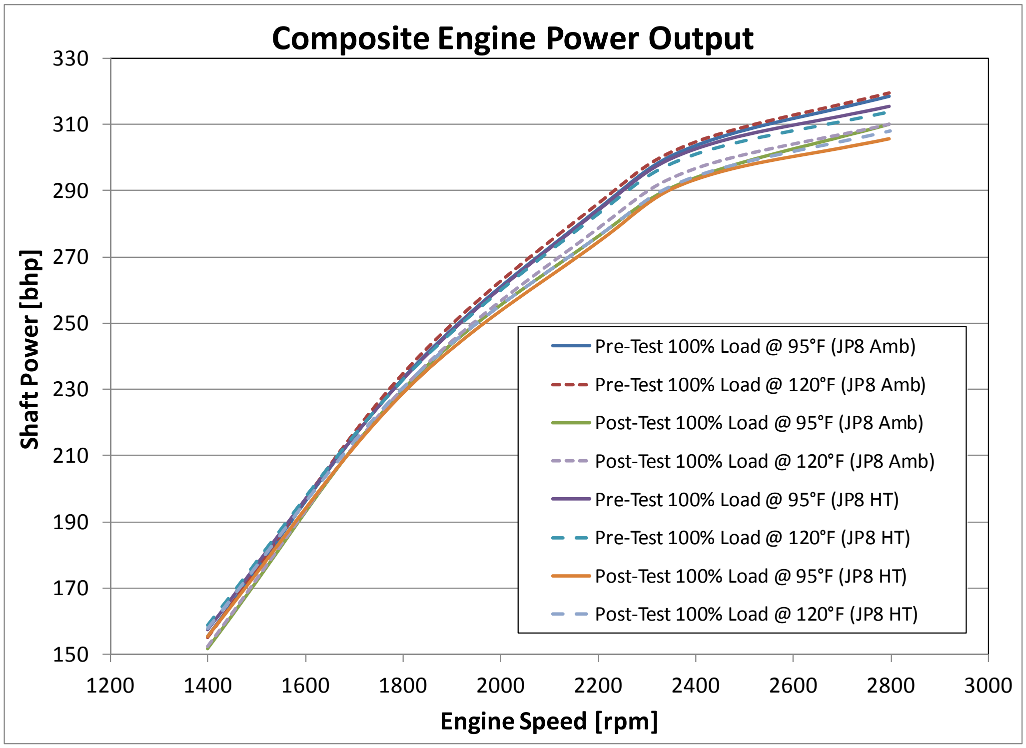


Figure D-8. Engine Power Output Comparing JP-8 Ambient and JP-8 High Temperature Tests

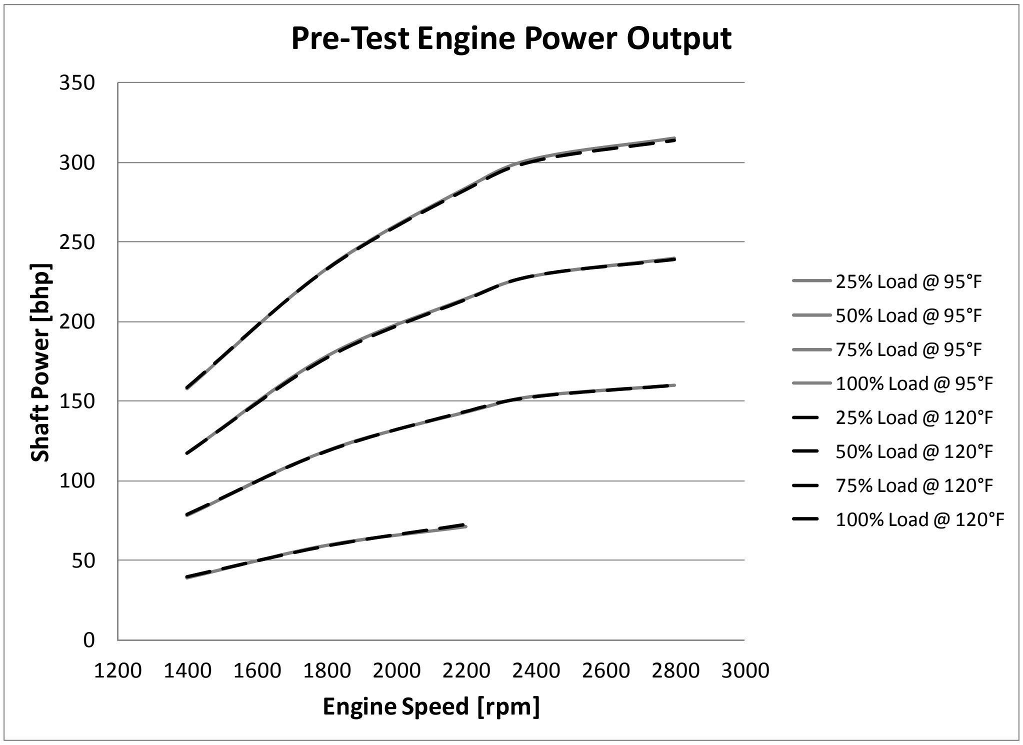


Figure D-9. Pre-Test Engine Power Output

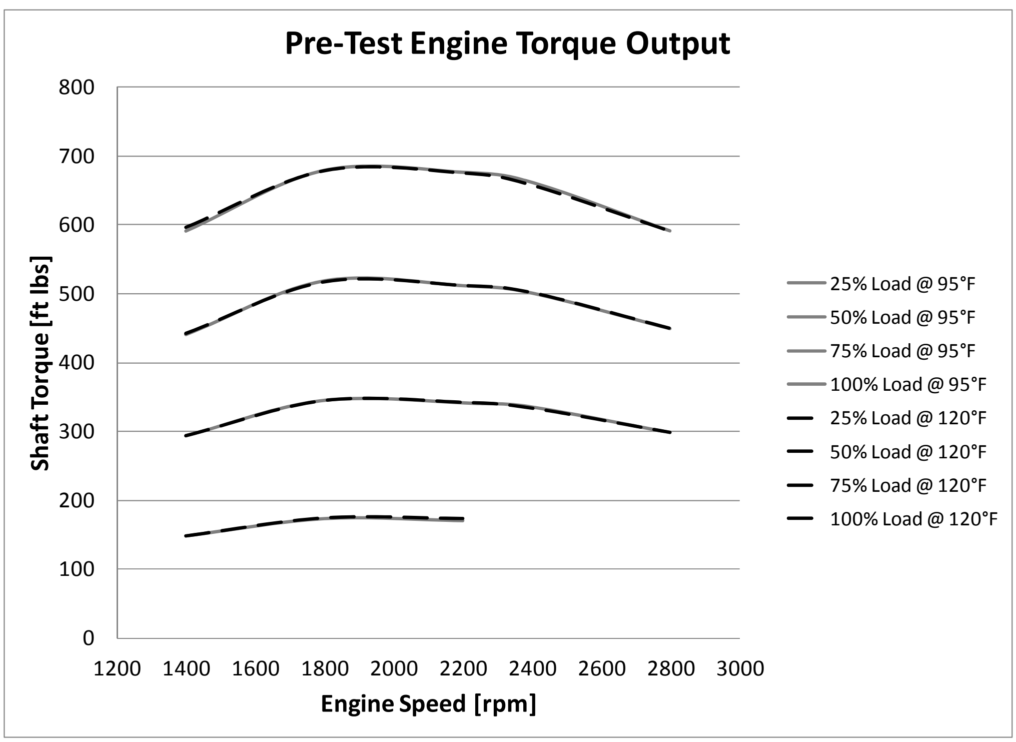


Figure D-10. Pre-Test Engine Torque Output

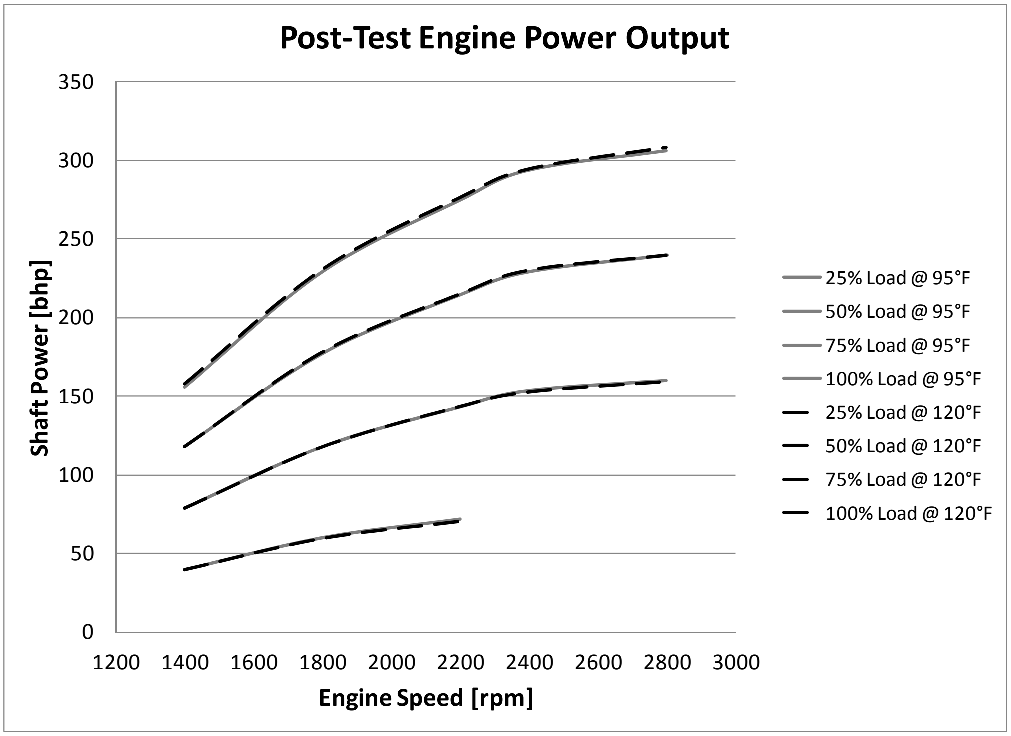


Figure D-11. Post-Test Engine Power Output

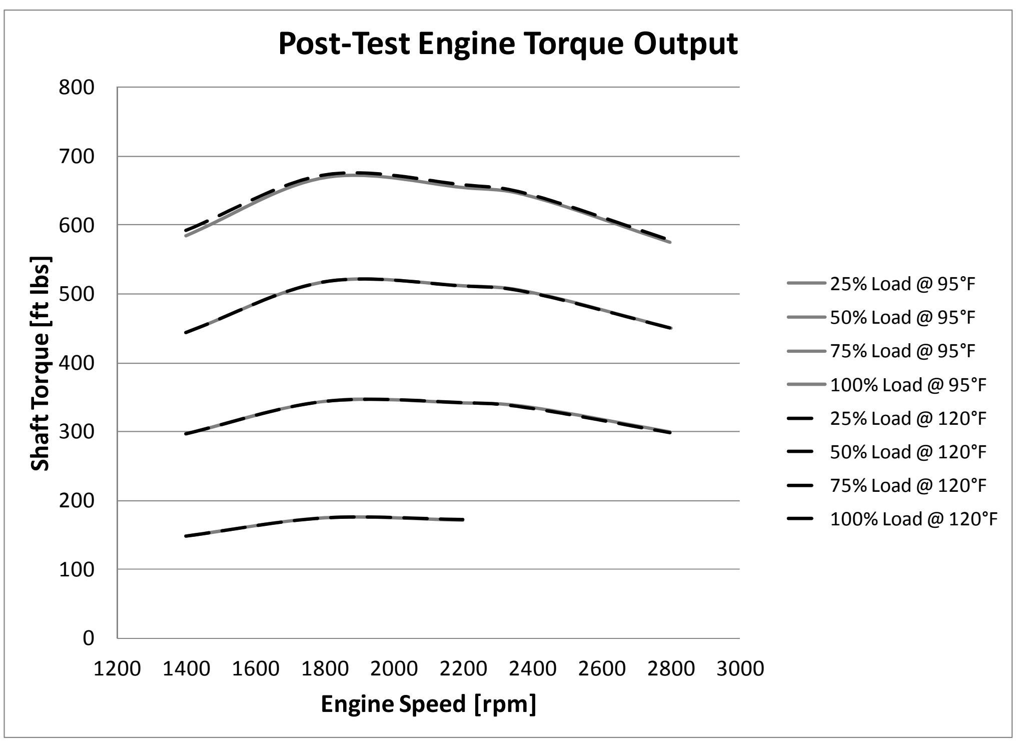


Figure D-12. Post-Test Engine Torque Output

D4.3 Engine Out Emissions

The engine out exhaust emissions for the Ford 6.7L Power Stroke diesel engine was measured as raw emissions downstream of the turbocharger outlet. The emissions instrumentation was a Horiba MEXA-1600D Motor Exhaust Gas Analyzer measurement system calibrated for detecting unburned hydrocarbon (HC), carbon monoxide (CO), carbon dioxide, oxygen, and oxides of nitrogen (NOx) species in the exhaust. Direct engine out exhaust emission measurements were taken during the pre, and post test power curve testing segments to document the engines overall condition, as tailpipe emission changes over the test duration could help identify fuel system degradation and engine performance changes. Mass based calculations were determined following methodology outlined in the Code of Federal Regulations, Title 40, Part 86, and Subpart D (2). Final mass based emissions values were then correlated to engine fuel consumption rates to provide direct comparison of mass emission produced per unit mass of fuel. These values are denoted as the Emissions Index (EI).

Data shown from the JP-8 high temperature evaluation are the emission measurements made prior-to, and after the 210-hour durability test. As there was little deviation between pre-test and post-test emission measurements, it is implicit that both the engine and fuel system integrity did not vary significantly due to the durability cycle with the high inlet temperature JP-8 fuel. Figure D-13 and Figure D-14 show the HC Emissions Index (HCEI), grams HC/lb fuel, for JP-8 over the performance matrices performed at the two fuel temperatures. As seen previously with other fuels (3), the 25% load points on the JP-8 show slightly higher HC, at the lean Air/Fuel Ratio (AFR) due to lower in-cylinder temperatures. The HCEI at 50% load was slightly elevated over the higher loads but less than the 25% load points. The 75% and 100% load points show similar HCEI response at all engine speeds. Generally at all engine loads the HCEI shows a trend of increases with increasing engine speed, due to shorter time available for the combustion to complete. At the higher speeds and high loads, increased mixing and increased in-cylinder temperatures help oxidize the hydrocarbons.

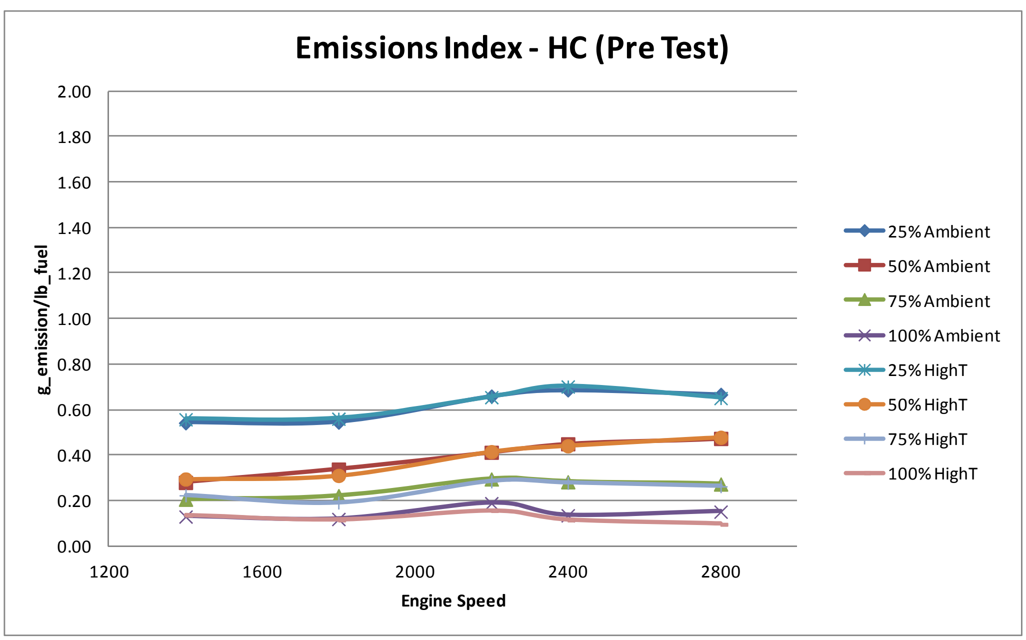


Figure D-13. AF-8029 JP-8, Pre Test HC Emission

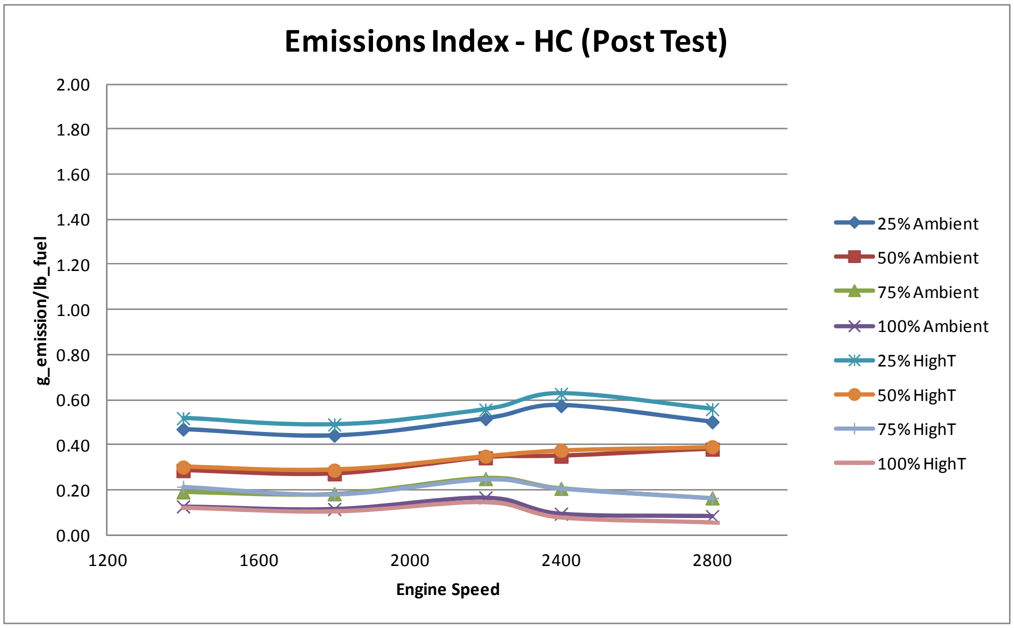


Figure D-14. AF-8029 JP-8, Post Test HC Emissions

Figure D-15 and Figure D-16 show the CO Emissions Index (COEI), grams CO/lb fuel, for the JP-8 over the performance matrices performed at two fuel temperatures, at each testing interval. The 25% load points reveal significantly higher CO due to lower in-cylinder temperatures, and incomplete combustion at lean Air/Fuel Ratios. The 50%, 75%, and 100% load points show similar COEI results at the two lowest engine speeds, but at higher engine speeds the 50% load points exhibit more incomplete combustion. The 75% and 100% load points have very similar COEI response with the JP-8/HRJ blend. At all engine loads the COEI increases with increasing engine speed, due to shorter time available for combustion completion.

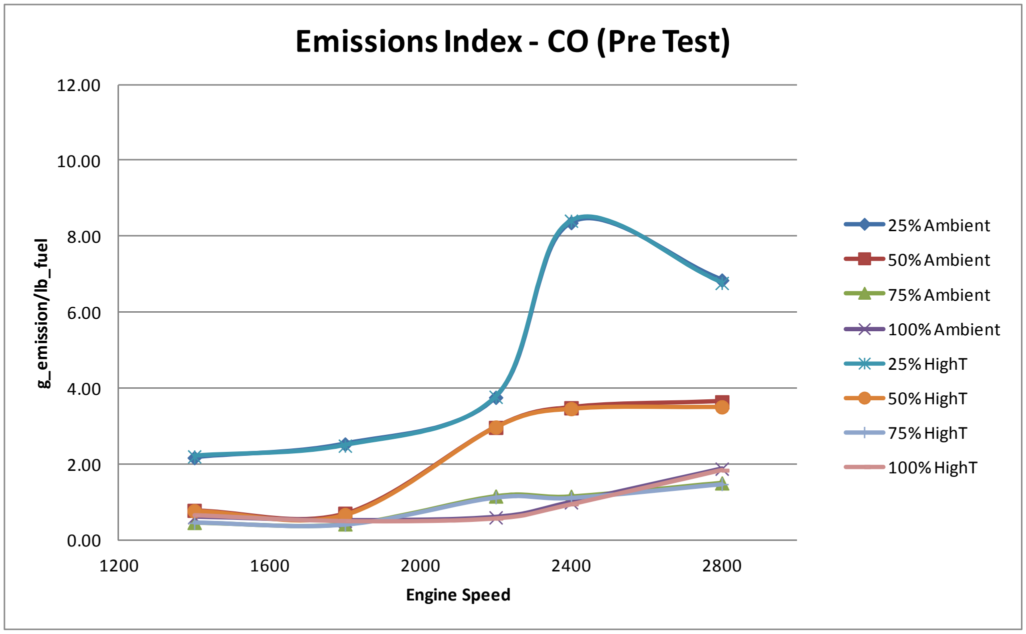


Figure D-15. AF-8029 JP-8, Pre Test CO Emissions

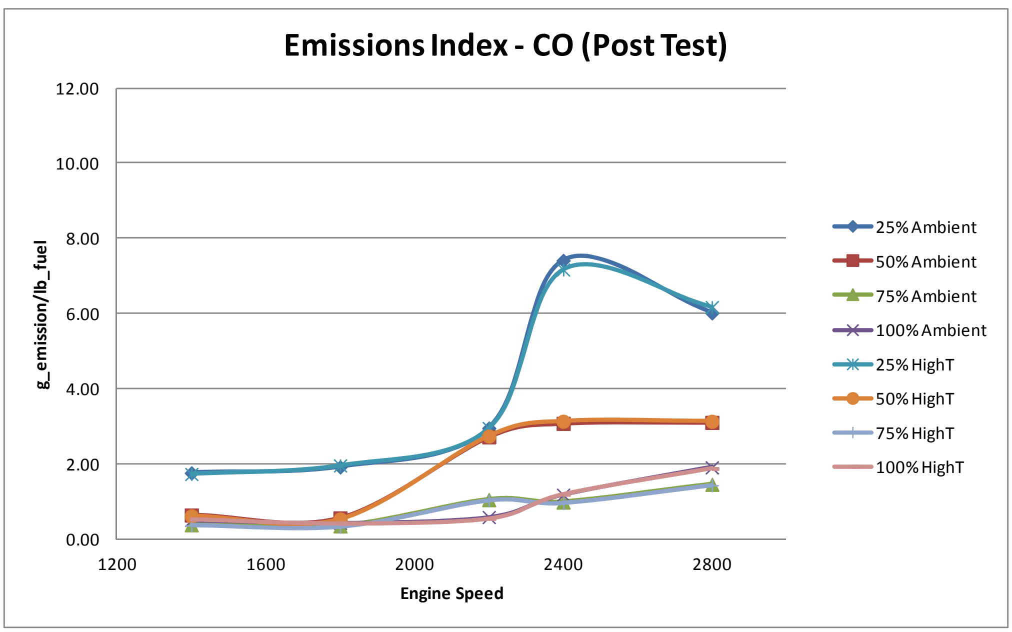


Figure D-16. AF-8029 JP-8, Post Test CO Emissions

Figure D-17 and Figure D-18 shows the NOx Emissions Index (NOxEI), grams NOx/lb fuel, for the JP-8 over the performance matrices performed at two fuel temperatures, at each testing interval. The 25% and 50% load points show the highest NOxEI, suggesting a greater portion of premixed burning during the heat release event. As the engine load increases the pilot fuel injection parameters are relatively more effective in rate-shaping the combustion event and the relative amount of NOx formed decreases. The decrease of NOxEI with increasing engine speed

may be attributed to less premixed fuel from less physical time available for evaporation and mixing during the ignition delay period. The JP-8 NOxEI responses were very consistent throughout the testing.

Figure D-19 shows the emission index values for the full load power curves generated at 95°F fuel inlet temperature using JP-8 fuel for both of the durability test conditions. The data represents the average of the pre and post emission curves for both tests. It should be noted one engine was utilized for the initial JP-8 test, and a different engine was used for the JP-8 high-temperature test. The HC emission index for the baseline JP-8 test reveals the effect of the leakage of the turbocharger seal on the engine HC emissions; the other emission responses are quite consistent between the two engines.

Figure D-20 shows the emission index values for the full load power curves generated at 120°F fuel inlet temperature using JP-8 fuel. The data represents the average of the pre and post emission curves for both tests. The HC emission index for the baseline JP-8 test reveals the effect of the leakage of the turbocharger seal on the engine HC emissions; the other emission responses are quite consistent between the two engines. The operation of the Ford 6.7 L engine on JP-8 fuel at 70°C fuel inlet temperature did not appear to substantially alter the engine emission performance.

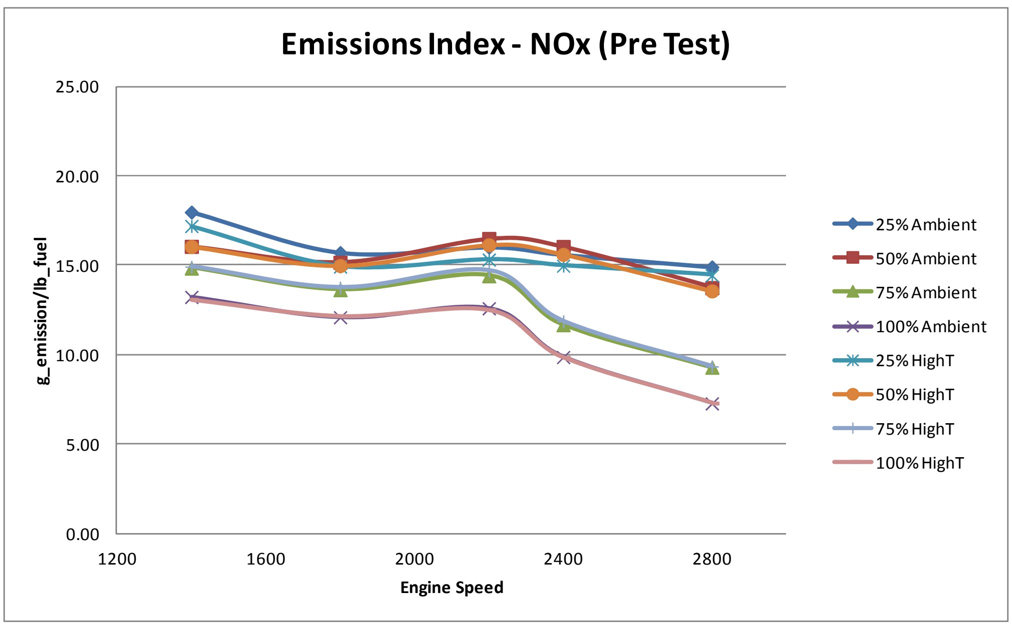


Figure D-17. AF-8029 JP-8, Pre Test NOx Emissions

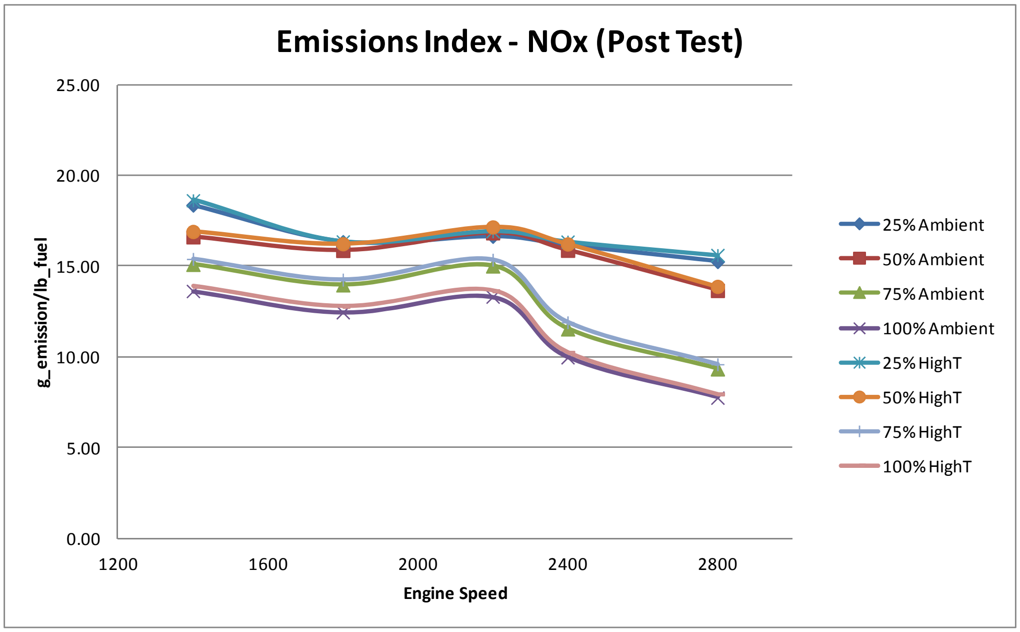


Figure D-18. AF-8029 JP-8, Post Test NOx Emissions

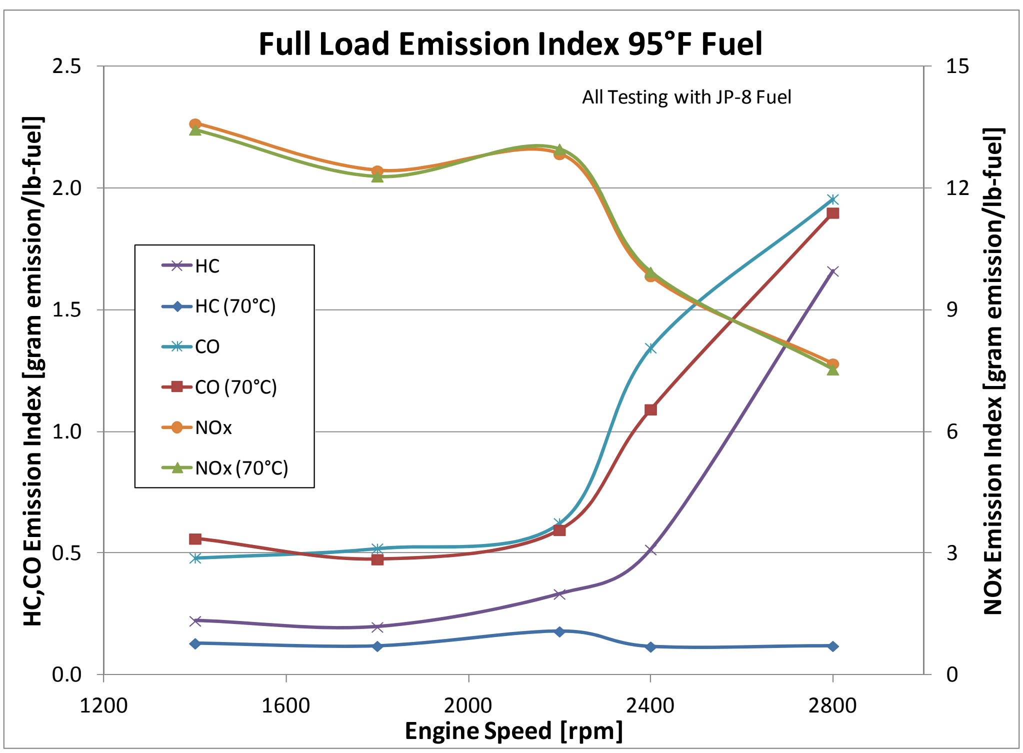


Figure D-19. JP-8 Tests Composite Power Curve Emission Indices with 95°F Fuel Inlet

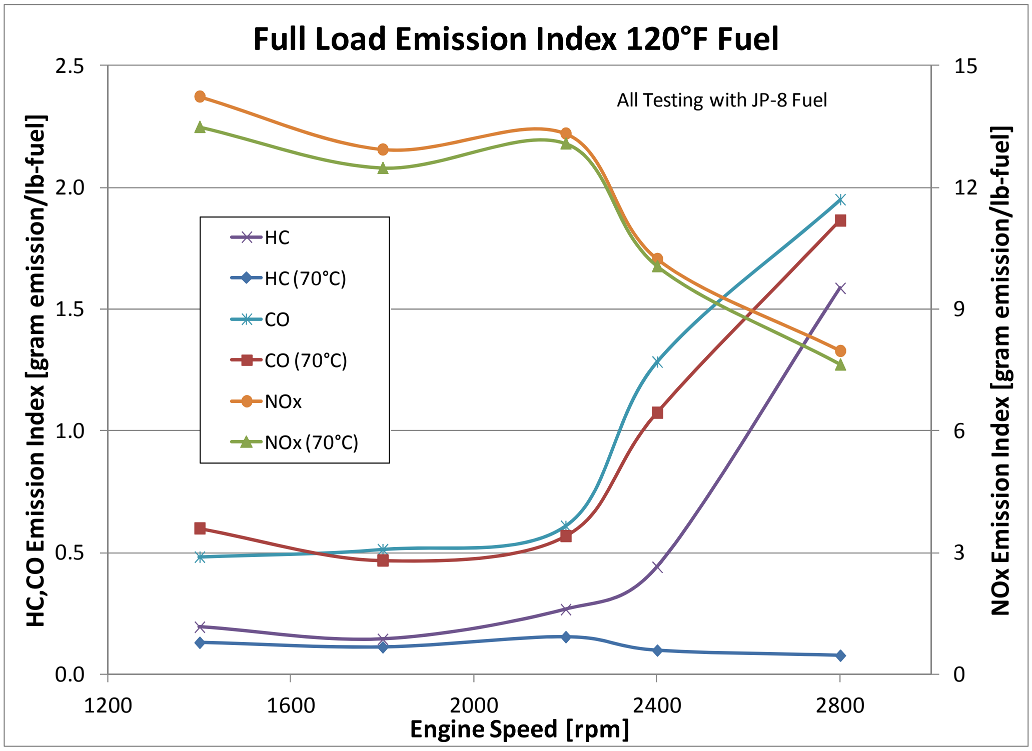


Figure D-20. JP-8 Tests Composite Power Curve Emission Indices with 120°F Fuel Inlet

D4.4 Engine Oil Analysis

Table D-7 below shows the engine used oil analysis over the test duration. No oil changes were required during the 210-hour test segment. Plots of various pertinent used oil property trends are shown subsequently.

D4.5 Engine Oil Analysis Trends

Figure D-21 shows the lubricant viscosity change throughout testing with the 5W-40 grade lubricant. The lubricant did thicken, increase out of grade (>16.3 cSt @ 100°C) prior to the 210-hour change, but as shown in Figure D-22 retained reserve alkalinity, or Total Base Number (TBN). Generally in engine testing, the TBN should be kept greater than 4.0, or the TBN should be greater than the Total Acid Number (TAN), to ensure the lubricant provides adequate engine protection. Since the lubricant retained its alkalinity during testing, no lubricant change was initiated. The baseline JP-8 test had very similar oil oxidation rates as the high fuel inlet temperature test. The lubricant was changed in the baseline JP-8 test at 168 hours due to viscosity change out of grade, but there was reserve TBN in the initial test fill. Operating at elevated fuel temperature only, did not affect lubricant degradation.

Table D-7. Engine Oil Analysis for 210-hour High Temperature JP-8 Diesel Engine Test

Property	ASTM Test	Test Hours										
		0	21	42	63	84	105	126	147	168	189	210
Density	D4052	0.858	0.861	0.862	0.865	0.868	0.872	0.875	0.878	0.882	0.885	0.888
Viscosity @ 100°C (cSt)	D445	14.2	15.1	15.2	15.8	16.2	16.7	17.1	17.7	18.3	18.9	19.7
Total Base Number (mg KOH/g)	D4739	8.4	6.9	6.3	5.9	5.9	5.6	5.2	5.3	4.6	4.4	4.7
Total Acid Number (mg KOH/g)	D664	1.9	2.3	2.1	2.4	2.5	2.5	2.8	3.0	3.2	3.2	3.6
Oxidation (Abs./cm)	E168 FTNG	0.0	1.6	2.2	3.9	5.5	6.6	7.2	8.4	8.9	9.7	12.9
Nitration (Abs./cm)	E168 FTNG	0.0	1.0	1.5	2.1	2.6	3.1	3.1	3.1	3.3	3.7	3.7
Soot	Soot	0.3					3.1					5.9
Wear Metals (ppm)	D5185											
Al		2	3	3	3	3	4	4	4	4	4	4
Sb		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ba		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
B		75	46	41	35	32	28	26	25	28	26	27
Ca		802	797	865	832	881	903	900	920	1006	1001	998
Cr		<1	<1	<1	1	1	2	2	2	3	4	4
Cu		<1	2	1	1	2	2	3	3	4	4	4
Fe		1	38	28	43	64	91	119	146	186	215	256
Pb		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mg		1128	1140	1175	1179	1228	1256	1277	1288	1341	1329	1372
Mn		<1	<1	<1	<1	<1	<1	<1	1	1	2	2
Mo		63	62	67	64	65	70	71	69	79	78	77
Ni		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1
P		1102	1019	1037	1004	994	1025	1045	1025	1104	1096	1082
Si		4	5	6	6	6	6	6	6	7	6	7
Ag		<1	<1	<1	<1	<1	<1	1	1	2	2	2
Na		6	6	8	7	8	7	9	8	10	10	9
Sn		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Zn		1300	1293	1256	1250	1272	1290	1322	1359	1350	1335	1401
K		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sr		<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
V		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ti		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cd		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

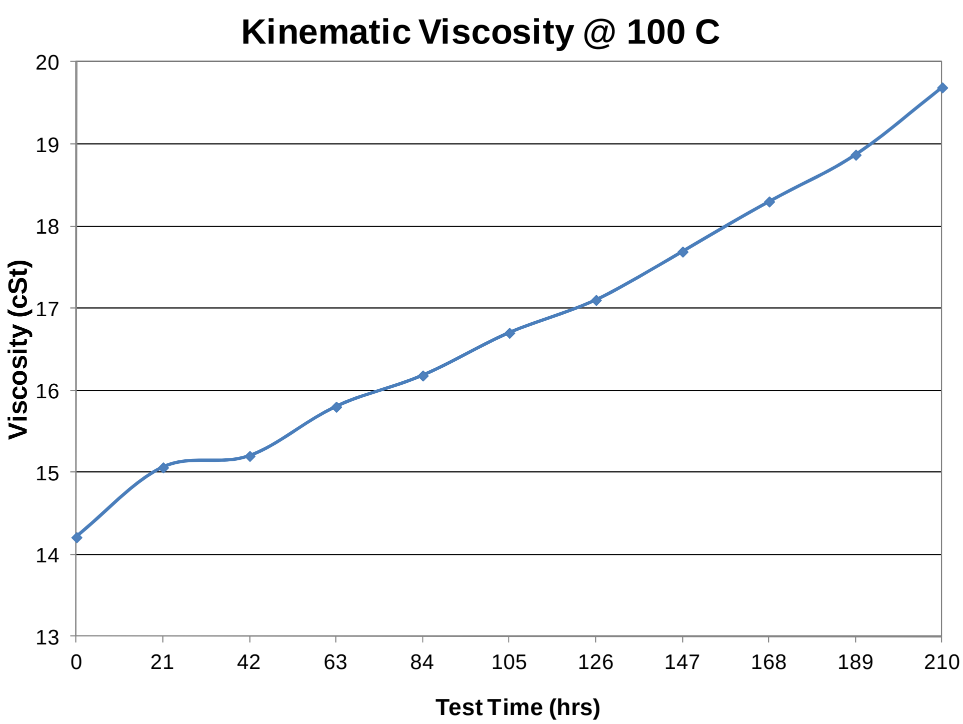


Figure D-21. Lubricant Kinematic Viscosity Change

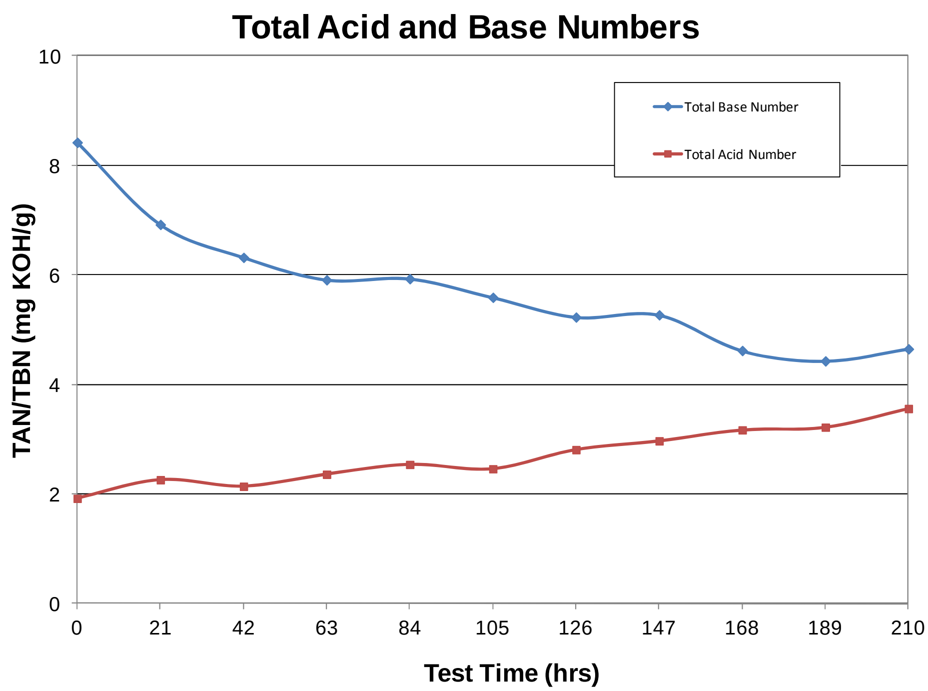


Figure D-22. Lubricant Acid and Base Number Change

The soot accumulation in the lubricant is shown in Figure D-23. A comparison of the soot accumulation and the viscosity change suggest soot accumulation in the lubricant was at least partially responsible, along with lubricant oxidation, for the viscosity increases that are shown in Figure D-21.

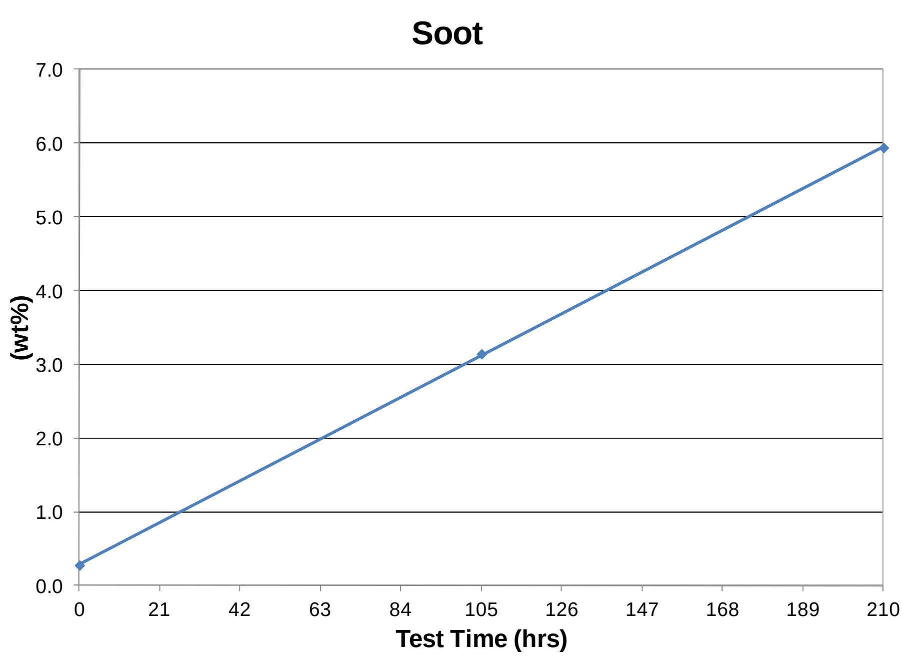


Figure D-23. Lubricant Soot Accumulation

D4.6 Oil Consumption Data

A tally sheet was kept of lubricant addition and samples from the 6.7L engine during testing. The tally sheet is shown as Table D-8. The average oil consumption per test hour for the JP-8 70°C fuel inlet temperature testing was 0.039 lbs/hour. By comparison the average oil consumption per test hour for the ambient JP-8 test for the initial test engine with leaking turbocharger seal was 0.046 lbs/hour.

Table D-8. Lubricant Additions over Test Duration

	Samples:					
Test Time	Date	Sample + Container Weight, lbs	-	Container Weight,lbs	=	Sample Weight, lbs
21 hr	10/15/11	0.30	-	0.06	=	0.24
42 hr	10/19/11	0.30	-	0.06	=	0.24
63 hr	10/20/11	0.31	-	0.06	=	0.25
84 hr	10/21/11	0.31	-	0.06	=	0.25
105 hr	10/22/11	0.31	-	0.06	=	0.25
126 hr	10/25/11	0.31	-	0.06	=	0.25
147 hr	10/26/11	0.30	-	0.06	=	0.24
168 hr	10/27/11	0.31	-	0.06	=	0.25
189 hr	10/28/11	0.30	-	0.06	=	0.24
210 hr	10/29/11	0.31	-	0.06	=	0.25
				Total Samples	=	2.46

	Additions:					
Test Time	Date	Addition + Container Weight, lbs	-	Container Weight,lbs	=	Addition Weight, lbs
21 hr	10/17/11	1.02	-	0.11	=	0.91
42 hr	10/19/11	0.99	-	0.11	=	0.88
63 hr	10/20/11	1.05	-	0.11	=	0.94
84 hr	10/21/11	1.15	-	0.11	=	1.04
105 hr	10/24/11	1.18	-	0.11	=	1.07
126 hr	10/25/11	1.92	-	0.11	=	1.81
147 hr	10/26/11	1.15	-	0.11	=	1.04
168 hr	10/27/11	1.73	-	0.11	=	1.62
189 hr	10/28/11	1.00	-	0.11	=	0.89
210 hr	10/31/11	0.65	-	0.11	=	0.54
				Total Additions	=	10.74

D4.7 Post Test Fuel Injection Hardware Inspection

The fuel injection pump can be broken down into four critical areas for evaluation: the interface of the fuel pump body bore and cam follower, cam and roller interface, cam and bushing (bearing) interface, and high pressure plunger and barrel. A visual inspection and description of each of these components can be seen below in Table D-9, followed by discussion of wear present and representative pictures. Overall inspections indicate the wear seen after 210-hours operation at elevated temperature with JP-8 was found to be similar to the wear results seen in all earlier Army/Air Force tests with the 6.7L engine.

Table D-9. Injection System Component Inspections

Test Hours	0	210	210	210
Part\Fuel	**New**	**DF-2**	**JP-8**	**JP-8-70°C FIT**
Volume Control Valve	**New**	**As new**	**As new**	**As new**
Pump Body	**Very light polish of bores**	**Very light polish of bores, top & bottom**	**Very light polish of bores, top & bottom**	**Light polish & very light scuff of Left bore, top & bottom; Light polish & very light scuff of Right bore, top, & mild scuff at bore bottom**
Pump Bushings	**Both new**	**Both as new**	**Both as new**	**Discoloration at zones corresponding to load direction, otherwise as new**
Cam	**Visible light grinding marks**	**Light polish, not measureable, seal contact wear**	**Light polish & very light burnish, not measureable, seal contact wear**	**Light polish & very light burnish, not measureable, seal contact wear**
Roller - Left	**New, bright & shiny**	**Light polish**	**Very light burnish & polish**	**Very light burnish & polish**
Roller - Right	**New, bright & shiny**	**Light polish**	**Very light burnish & polish**	**Very light burnish & polish**
Roller Shoe - L	**New**	**New, polish from plunger button**	**New, polish from plunger button**	**New, polish from plunger button**
Roller Shoe - R	**New**	**New, polish from plunger button**	**New, polish from plunger button**	**New, polish from plunger button**
Follower - L	**New**	**Very light polish**	**Polish, very light scuff, top & bottom**	**Polish, light scuff, top & bottom**
Follower - R	**New**	**Very light polish**	**Polish, very light scuff, top & bottom**	**Polish, light scuff, top & bottom, mild scuff side corresponding to pump bore mild scuff**
Plunger - L	**New**	**As new, very light polish on plunger button, more than right**	**As new, light polish on plunger button, more than right**	**As new, light polish on plunger button**
Plunger - R	**New**	**As new, very light polish on plunger button**	**As new, light polish on plunger button**	**As new, light polish on plunger button**
Barrel - L	**New**	**As new**	**As new**	**As new**
Barrel - R	**New**	**As new**	**As new**	**As new**
Inlet Check - L	**New**	**As new**	**As new**	**As new**
Inlet Check -R	**New**	**As new**	**As new**	**As new**

D4.8 Post Test Fuel Injection Hardware Photos (no magnification)

The following photos document the post test fuel injection hardware condition. Figure D-24 and Figure D-25 below show a representative photo of the HPCR pump body. Frame of reference for left and right notations are taken from Figure D-25 as the pump is installed in the engine.

Figure D-24. HPCR Pump Body, Front (Representative Photo)

Figure D-25. HPCR Pump Body, Rear (Representative Photo)

Figure D-26 shows the left hand pump body bore for both JP-8 tests. Figure D-27 shows a close up picture of the light polish found on the bore surface from interaction with the cam follower assembly. The wear present on the pump body bore and cam follower surfaces were found to be similar to previous fuels testing. The bores in each of the pumps showed some polishing on their surface from interactions with the cam follower. Markings tended to be present primarily at the

top and bottom of the travel area of the follower, which is consistent with areas of largest side loading present on the follower from the forces applied by the pumps camshaft and plunger return spring. A new unused pump also shows similar but smaller markings likely produced at end of line testing during manufacturing.

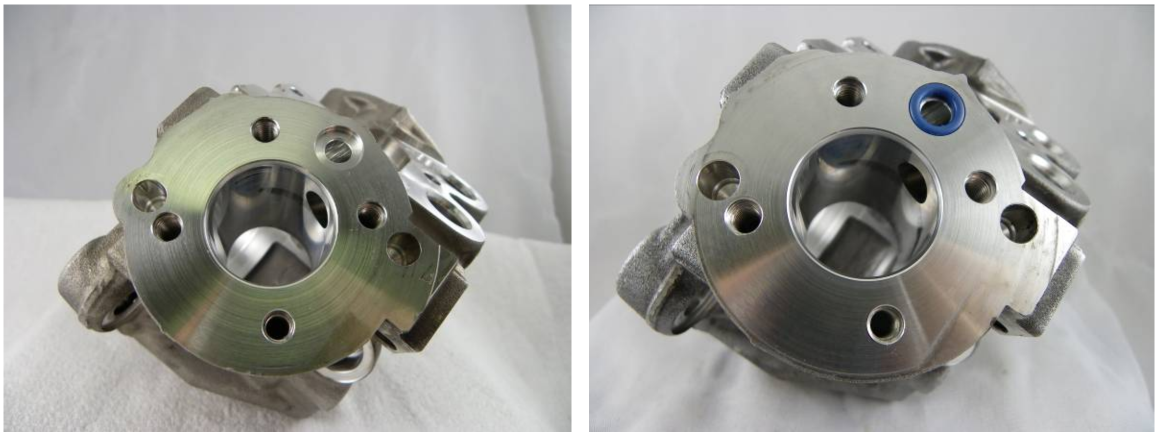


Figure D-26. AF-8029 JP-8 (HT Left), Post Test, Left Pump Bore, JP-8 (Base Right)

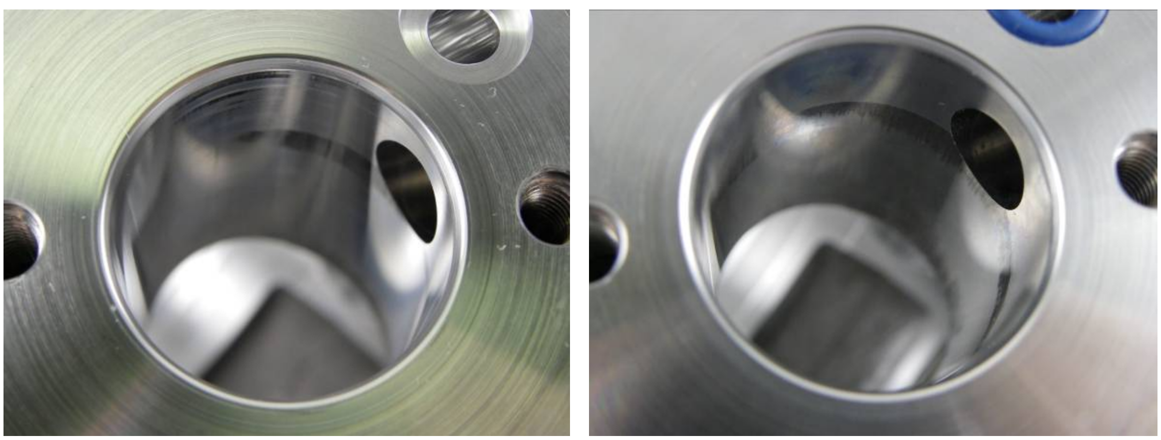


Figure D-27. AF-8029 JP-8 (HT Left), Post Test, Left Pump Bore Close-up, JP-8 (Base Right)

Figure D-28 shows the right hand pump body bore for both JP-8 tests. Figure D-29 below shows a close up picture of the light polish found on the bore surface, similar to the left hand bore. The follower bore wear for the left and right sides of the pump were very similar.

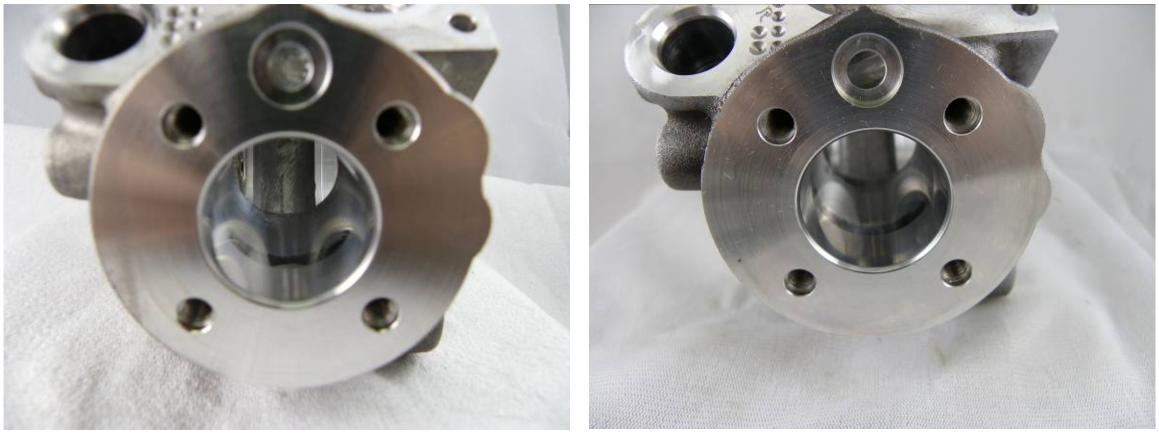


Figure D-28. AF-8029 JP-8 (HT Left), Post Test, Right Pump Bore, JP-8 (Base Right)

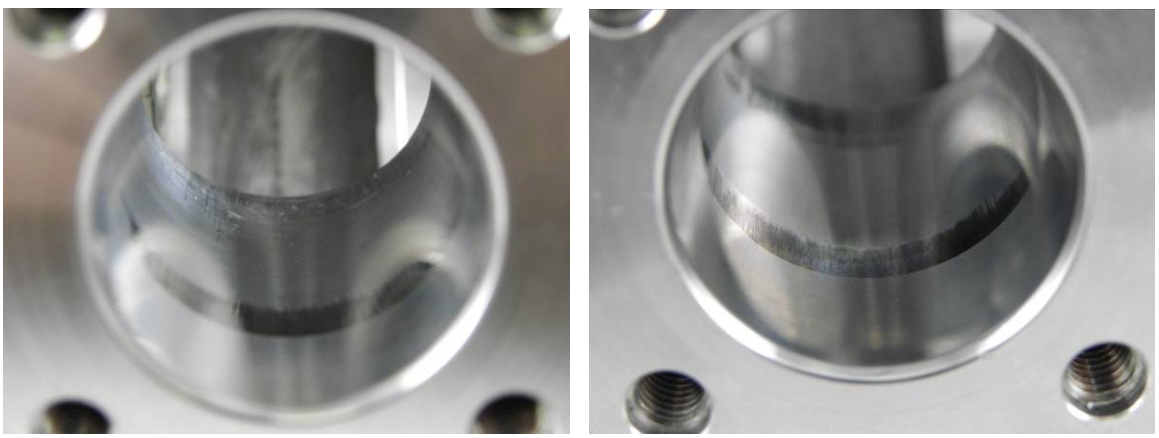


Figure D-29. AF-8029 JP-8 (HT Left), Post Test, Right Pump Bore Close-up, JP-8 (Base Right)

Figure D-30 shows the left bore cam follower and roller assemblies for both JP-8 tests. The followers were oriented to show the most severe areas of wear present on the follower surface. All follower surfaces showed polishing and light scuffing on their surfaces consistent with the polishing found on the pump bore surface. This again corresponded with areas that typically experience the greatest side load forces. Follower assemblies from the high temperature JP-8 evaluation tended to show a slightly increased area of scuffing as compared to previous tests, which is consistent with the reduction in overall viscosity due to the elevated fuel inlet temperature Figure D-31 below shows the left hand roller surface, with light burnishing evident for both JP-8 tests.

Figure D-30. AF-8029 JP-8 (HT Left), Left Cam Follower, JP-8 (Base Right)

Figure D-31. AF-8029 JP-8 (HT Left), Left Cam Follower Roller, JP-8 (Base Right)

Figure D-32 shows the left cam follower under crown and the contact area with the high pressure plunger head. Figure D-33 shows the left hand high pressure plunger. Note the similar contact markings where it contacts the follower under crown. Polishing at this interface was visible, but no physical wear was tactically distinguishable.

The barrel and plunger assemblies for the test did not show any wear distinguishing themselves from the new unused components. All surfaces treating to the high pressure plunger was intact and showed no variation. The inside diameter of the barrel surfaces also appeared to be smooth and unworn.

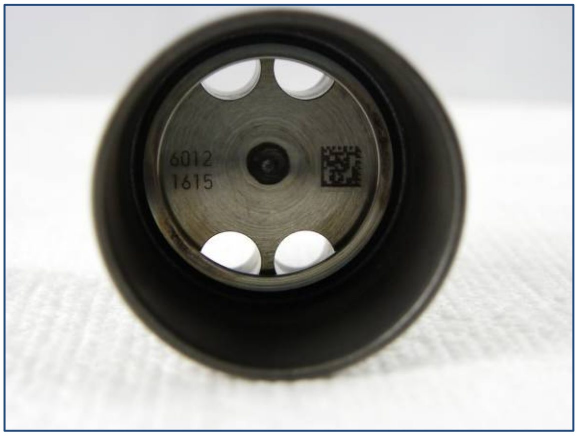


Figure D-32. AF-8029 JP-8 (HT Left), Left Cam Follower under Crown, JP-8 (Base Right)


Figure D-33. AF-8029 JP-8 (HT Left), Left High Pressure Plunger, JP-8 (Base Right)

Figure D-34 shows the right bore cam follower and roller assemblies for both JP-8 tests. The followers were oriented to show the most severe areas of scuffing present on the follower surface. Figure D-35 below shows the right hand roller surface. The follower and roller wear for the left and right sides of the pump were very similar overall to wear seen in previous testing, and show no indication of additional aggressive wear due to the increased fuel inlet temperature.

Figure D-34. AF8029 JP-8 (HT Left), Right Cam Follower, JP-8 (Base Right)

Figure D-35. AF-8029 JP-8 (HT Left), Right Cam Follower Roller, JP-8 (Base Right)

Figure D-36 shows the right cam follower under crown and the contact area with the high pressure plunger head. Figure D-37 shows the right hand high pressure plunger. Similar to the left hand assembly, polishing at this interface was visible, but no physical wear was tactically distinguishable. The right barrel and plunger assembly wear was similar to that seen on the left, and similar to all previously run test fuels.

Figure D-36. AF-8029 JP-8 (HT Left), Right Cam Follower under Crown, JP-8 (Base Right)

Figure D-37. AF-8029 JP-8 (HT Left), Right High Pressure Plunger, JP-8 (Base Right)

Figure D-38 and Figure D-39 below show the pump body rear and front camshaft bushings respectively for both JP-8 tests. The bushings showed no signs of wear with the JP-8 at elevated temperatures. This was consistent with all of the other fuels tested in the 6.7 L engine using the wheeled vehicle cycle.

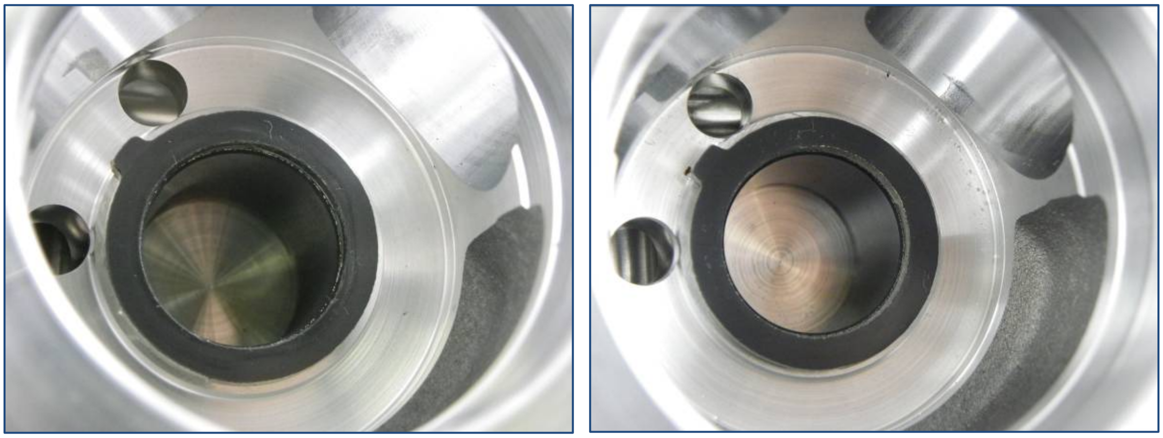


Figure D-38. AF-8029 JP-8 (HT Left), Rear Pump Body Camshaft Bushing, JP-8 (Base Right)

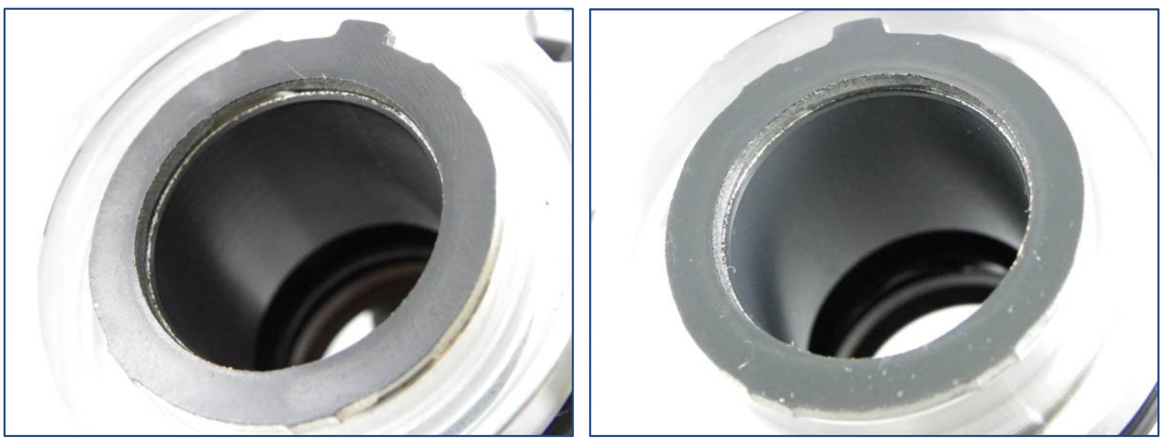


Figure D-39. AF-8029 JP-8 (HT Left), Front Pump Body Camshaft Bushing, JP-8 (Base Right)

Figure 40 shows the HPCR fuel injection pump camshaft for both JP-8 tests. As was seen with the other tests, only light burnishing is present at the cam lobe/roller follower contact, and slight wear is seen at the contact location of the shaft seal.

Figure D-40. AF-8029 JP-8 (HT Left), HPCR Pump Camshaft, JP-8 (Base Right)

Figure D-41 shows a close-up of one of the cam lobe peaks, from both JP-8 tests, which are in very good condition with only light polish and light burnishing for this fuel-lubricated, heavily-loaded contact. The burnishing is slightly heavier after the elevated fuel inlet temperature JP-8 test.

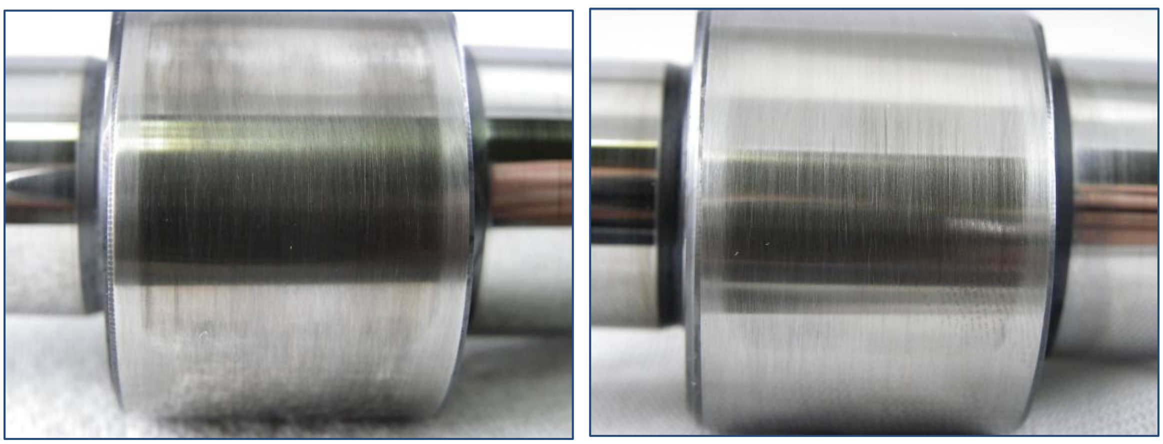


Figure D-41. AF-8029 JP-8 (HT Left), HPCR Pump Camshaft, Lobe Surface Close-up, JP-8 (Base Right)

D4.9 Post Test Fuel Injection High Magnification Photos

Consistent with the high pressure fuel pump inspection, fuel injectors from the test were removed and disassembled for inspection and photographs. Due to the size of the fuel injectors internal components, many photos were taken under magnification to better determine any wear patterns present. Inspections were made to the hydraulic coupler pistons, control valve, control plates, injector needle, and nozzle.

Figure D-42 shows an injector nozzle tip for each of the JP-8 tests. No substantial deposit formations were seen under low magnification. Figure D-43 below shows the injector needle tips. No abnormal wear, deposits, or markings were found on either of the tapered tips.

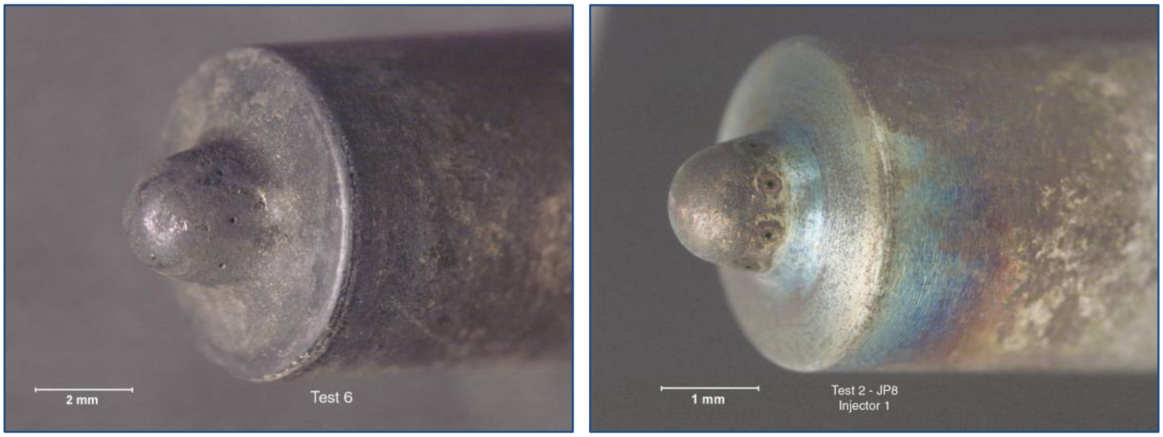


Figure D-42. AF-8029 JP-8 (HT Left), Injector Nozzle, JP-8 (Base Right)

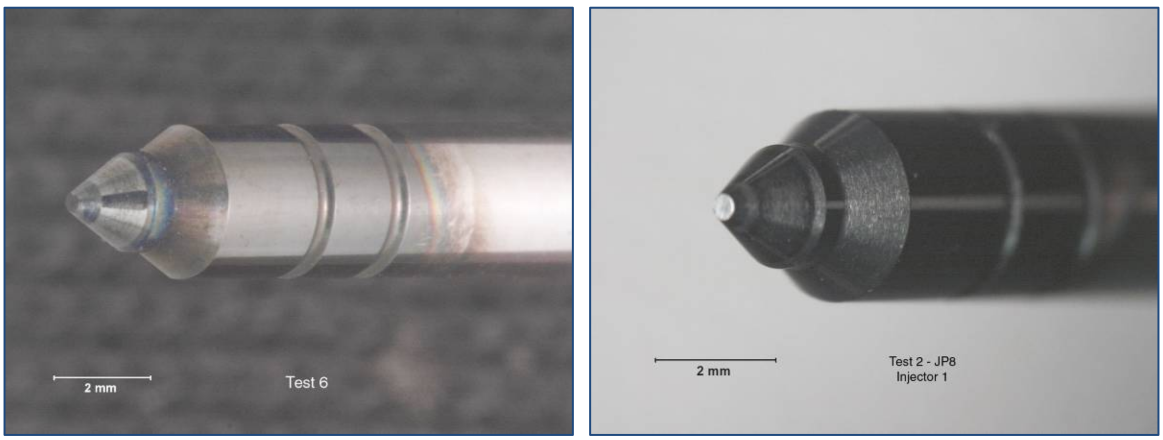


Figure D-43. AF-8029 JP-8 (HT Left), Injector Needle, JP-8 (Base Right)

Consistent with what was seen in previous testing, the only internal injector components showing any appreciable wear patterns were the upper pistons of the hydraulic coupling. As previously explained in the fuel system description section, the hydraulic coupler is used to translate the small linear movement of the piezoelectric-stack to a larger linear movement to operate the injector control valve and regulate needle lift. From the inspection, it appeared that the piezoelectric-stack imparts a slight side load on the upper piston causing a reacting wear scar to be formed on the outer piston surface. This wear scar was seen in each of the test fuels in previous testing (3), and was found to be overall similar in size and condition between during the high temperature JP-8 evaluation. Figure D-44 and Figure D-45 show the side profile of the upper hydraulic coupler piston for both JP-8 tests. Although this wear did not impact the testing at hand, this type of wear is typical of wear that can be detrimental to fuel injector function if continued. Binding or sticking of the hydraulic coupler has the potential to impair the action of the control valve which can potentially result in no fuel being injected into the engine, or a constant flow of injected fuel. Either of these occurring during engine operation would require immediate fuel injector replacement to ensure proper engine operation.

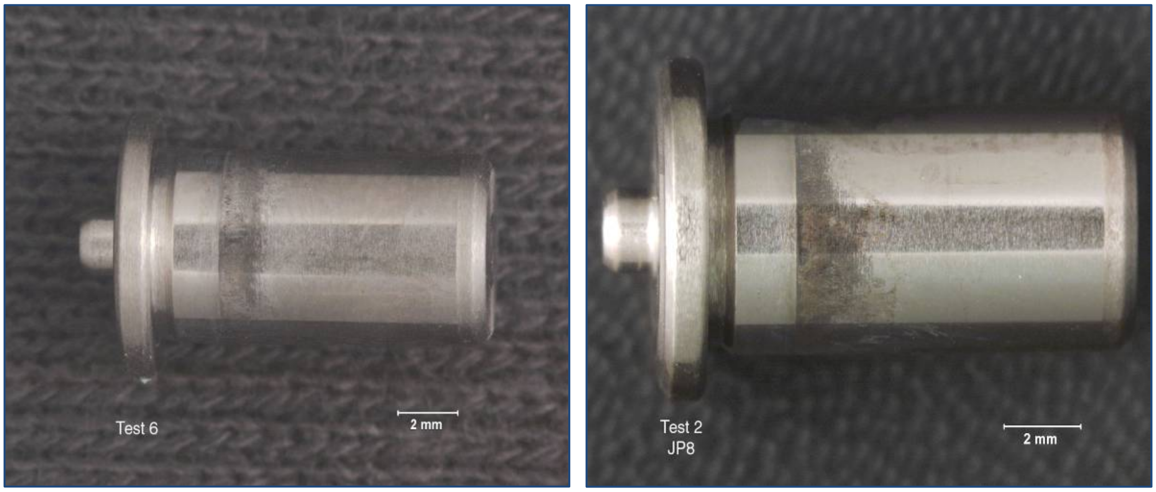


Figure D-44. AF-8029 JP-8 (HT Left), Upper Hydraulic Coupler Piston, Profile, JP-8 (Base Right)

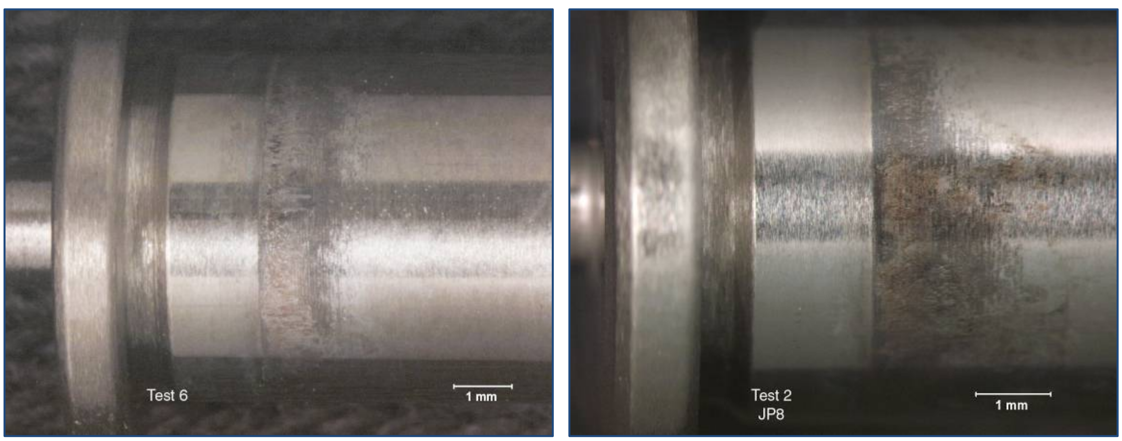


Figure D-45. AF-8029 JP-8 (HT Left), Lower Hydraulic Coupler Piston, Wear Scar Close-up, JP-8 (Base Right)

Figure D-46 and Figure D-47 show the upper and lower hydraulic coupler pistons contact surfaces respectively for both JP-8 tests. No noticeable wear was seen on the piston surface interface, or at the heads of the piston at the piezoelectric stack and control valve interface.

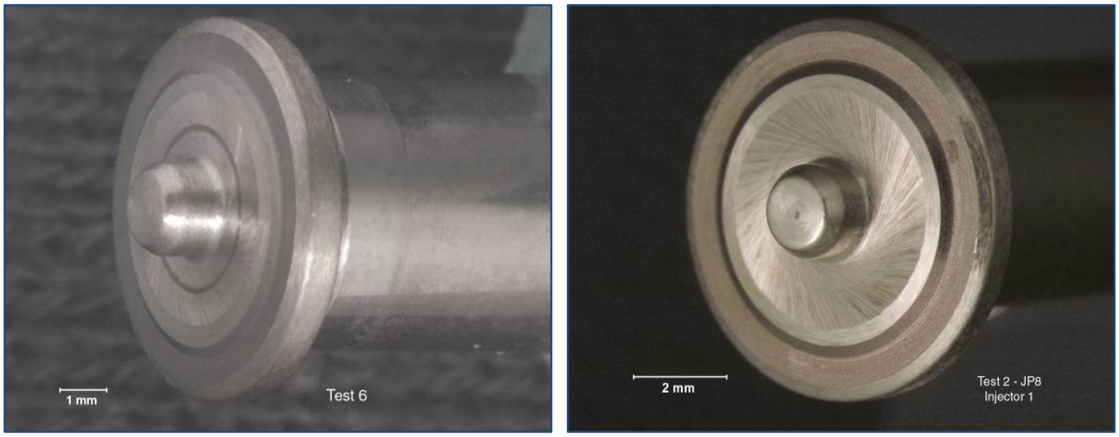


Figure D-46. AF-8029 JP-8 (HT Left), Upper Hydraulic Coupler Piston, JP-8 (Base Right)

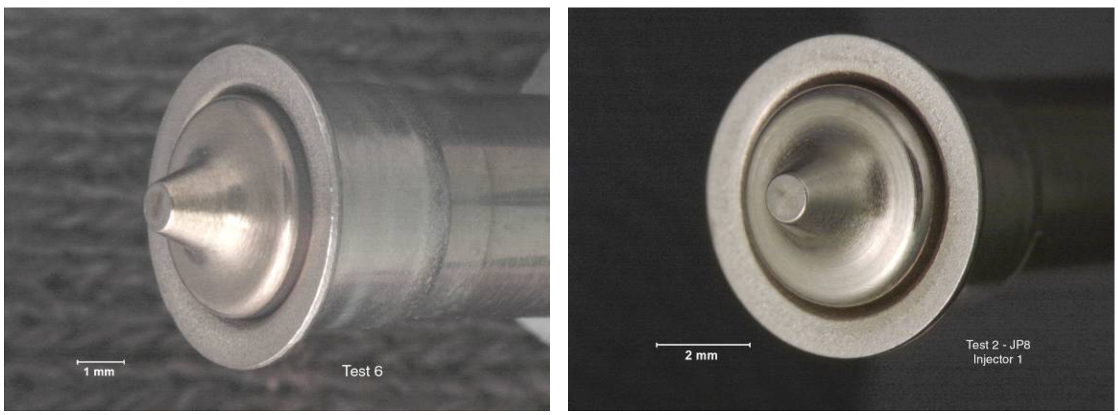


Figure D-47. AF-8029 JP-8 (HT Left), Lower Hydraulic Coupler Piston, JP-8 (Base Right)

Figure D-48 and Figure D-49 show the top and bottom surfaces of the intermediate plate for both JP-8 tests. This plate contains the fuel control passages used to manipulate the needle position.

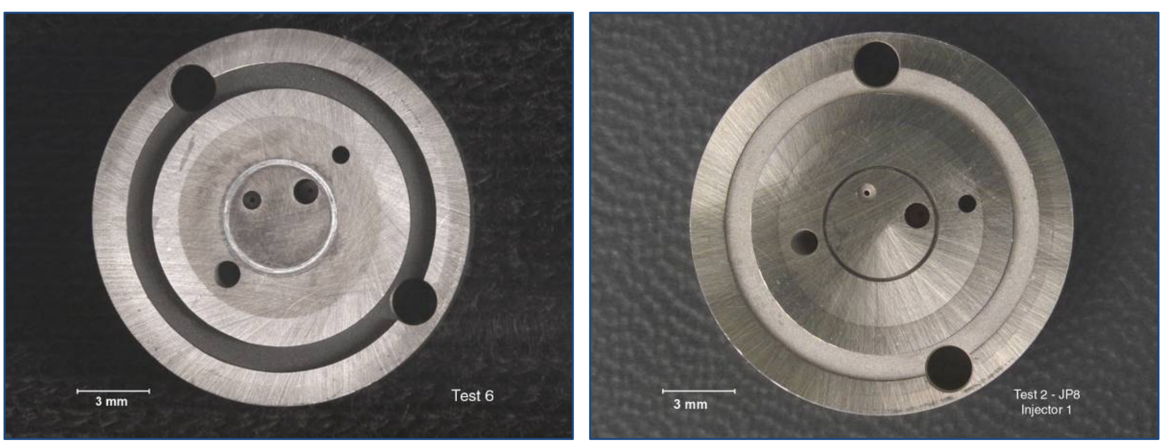


Figure D-48. AF-8029 JP-8 (HT Left), Intermediate Plate (Top), JP-8 (Base Right)

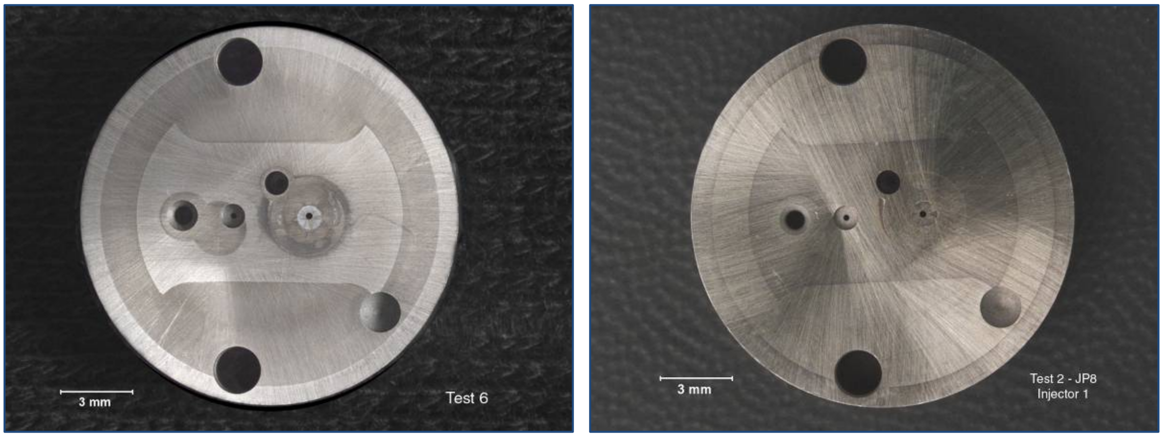


Figure D-49. AF-8029 JP-8 (HT Left), Intermediate Plate (Bottom), JP-8 (Base Right)

Figure D-50 and Figure D-51 show the top and bottom of the control valve plate for both JP-8 tests. Similar to previous testing, light fuel deposition was evident on the surfaces. The control valve sits in the bore shown in Figure D-51. The lower piston of the hydraulic coupler operates in the bore shown in Figure D-50.

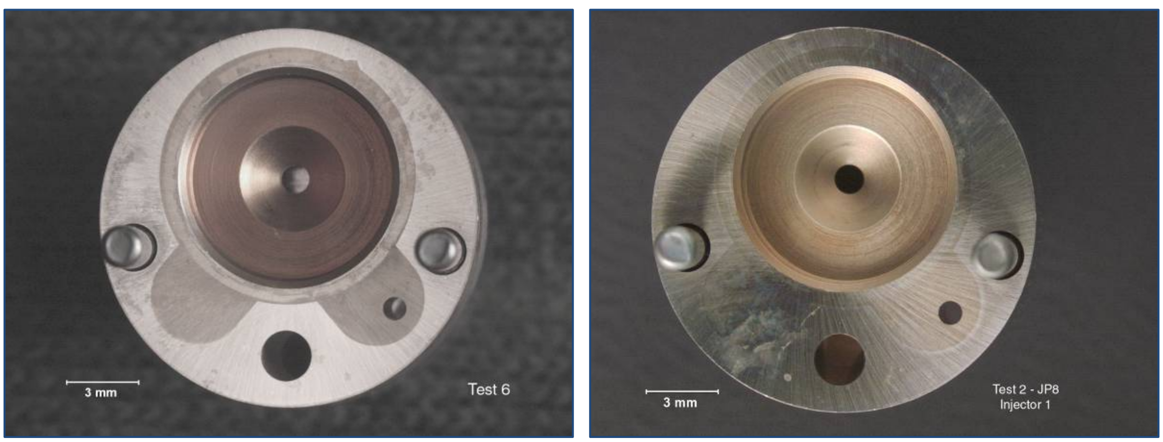
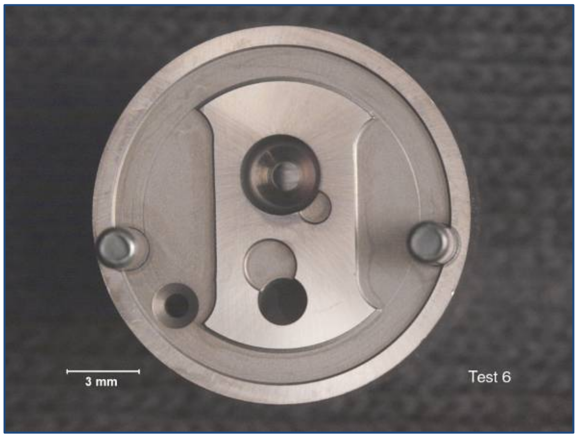


Figure D-50. AF-8029 JP-8 (HT Left), Control Valve Plate (Top) , JP-8 (Base Right)



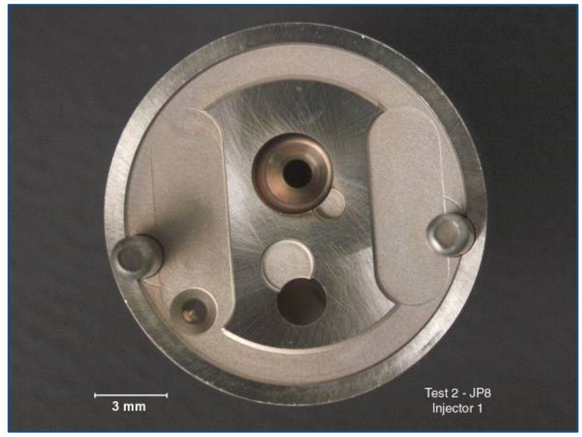
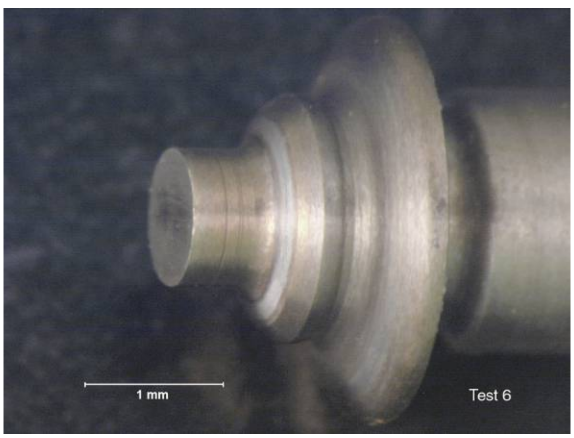


Figure D-51. AF-8029 JP-8 (HT Left), Control Valve Plate (Bottom) , JP-8 (Base Right)

Figure D-52 shows the control valves for both JP-8 tests, which regulates the pressure on top of the injector needle, thus controlling needle lift and injection timing. No unusual wear was found on the control valve.



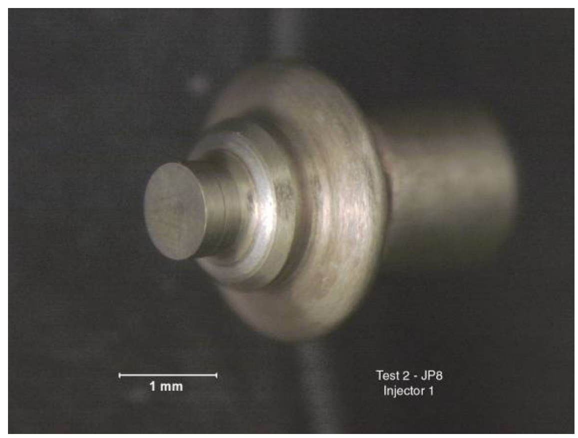


Figure D-52. AF8029 JP-8 (HT Left), Fuel Injector Control Valve, JP-8 (Base Right)

D5.0 CONCLUSIONS

Testing conducted supports that the Ford 6.7 L fuel lubricated high pressure common rail fuel injection system can be successfully operated using JP-8 at elevated fuel inlet temperatures. Even at the minimum lubricity enhancing treat rates, the tested JP-8 provided adequate component protection and system performance compared to previous fuels testing. No unusual fuel related operating conditions were experienced throughout testing, and engine performance remained consistent and satisfactory throughout. Post test fuel injection system inspections found used components to be in similar condition throughout all tests operated to date for U.S. Army and U.S. Air Force test fuel programs performed by SwRI in the Ford 6.7 L engine (3).

D6.0 RECOMMENDATIONS

Ford 6.7 L fuel injection system robustness has been observed utilizing a wide range of petroleum and synthetic test fuels at nominal fuel inlet temperatures, and with a petroleum JP-8 fuel at high fuel inlet temperatures. It is recommended high fuel inlet temperatures testing with synthetic kerosene fuels, that also may exhibit low density and low viscosity, be evaluated in the Ford 6.7 L engine.

D7.0 REFERENCES

1. Development of Military Fuel/Lubricant/Engine Compatibility Test, CRC Report 406, January 1967.
2. Electronic Code of Federal Regulations, Title 40, Part 86, Subpart D, March 15, 2011.
3. Brandt, A.C.; Yost, D.M., "*Evaluation of Military Fuels using a Ford 6.7L Powerstroke Diesel Engine",* Interim Report TFLRF No. 415, ADA560574, August 2011.
4. Brandt, A.C.; Yost, D.M., "*Evaluation of 50/50 Hydroprocessed Renewable Jet Fuel & JP-8 in the Ford 6.7L High Pressure Common Rail Diesel Engine",* AFRL-RZ-WP-TR-2012-XXXX.

D8.0 ACRONYMS & ABBREVIATIONS

Acronym	Description
°	Degree
%	Percent
Al	Aluminum
CN	Cetane Number
CO	Carbon Monoxide
COA	Certificate of Analysis
COTS	Commercial Off-The-Shelf
Cu	Copper
DFCM	Diesel Fuel Condition Module
EGR	Exhaust Gas Recirculation
EI	Emissions Index
Fe	Iron
FIP	Fuel Injection Pumps
HC	Hydrocarbon
H/C	Hydrogen/Carbon atom ratio
HEFA	Hydroprocessed Esters and Fatty Acids
HPCR	High Pressure Common Rail
HofC	Heat of Combustion
HRJ	Hydroprocessed Renewable Jet
IQT	Ignition Quality Test
NOx	Oxides of Nitrogen
PCM	Powertrain Control Module
PCV	Pressure Control Valve
Pb	Lead
PPM	Parts per Million
SwRI	Southwest Research Institute
TAN	Total Acid Number
TBN	Total Base Number
TWVC	Tactical Wheeled Vehicle Cycle
ULSD	Ultra Low Sulfur Diesel fuel
VCV	Volume Control Valve

APPENDIX E

FIT-FOR-PURPOSE TESTING OF ALTERNATIVE AVIATION FUELS

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E1.0 EXECUTIVE SUMMARY

The overall aim of this effort was to provide fit-for-purpose testing and subject matter expertise to UTC and AFRL to support the evaluation of emerging synthetic aviation fuels. This report contains information on the evaluation of various alternative aviation fuels including: R8, GEVO ATJ (alcohol-to-jet), Neste Oil NExBTL HRJ (from waste oils), and Rentech FT-SPK. This report also contains the results of some special topic studies including water solubility, speed-of-sound, and isentropic bulk modulus.

Although most of the fuels studied to date (particularly the 50/50 blends) would likely meet a standard jet fuel specification, each of the synthetic fuels in this study exhibit their own unique behavior imparted on the fuel by the particular feedstock. Some of the behavior noted in this report is critical to fuel performance such as additive response, water solubility, and distillation characteristics. This further reinforces the need for fit-for-purpose testing to identify those unusual characteristics and to ensure that they are not significantly outside our current experience with petroleum-derived jet fuels.

The cumulative work to date provides strong evidence that blends composed of 50% synthetic fuel (FT IPK, HRJ, ATJ, etc) and 50% petroleum-derived fuel will be more than adequate as drop-in replacements for current petroleum-based fuels.

E2.0 INTRODUCTION

The work reported herein is a continuation of prior work to provide fit-for-purpose testing and subject matter expertise to UTC and AFRL in support of emerging synthetic aviation fuels. This report contains information on the following subjects:

- Evaluation of alternative aviation fuels
  - R8 HRJ
  - GEVO ATJ
  - Neste Oil NExBTL HRJ
  - Rentech FT-SPK
- Miscellaneous Analyses
  - Baseline O-ring Testing (Jet A and JP-8)
  - Opti-Lube XPD Lubricity Evaluations by HFRR
  - Fuel Analysis for FAA CLEEN* Program
  - Water Solubility Study
  - Speed-of-Sound and Isentropic Bulk Modulus Study

* Continuous Lower Energy, Emissions, and Noise

E3.0 METHODS, ASSUMPTIONS, AND PROCEDURES

E3.1 Sample Technology

Throughout this report, various means of identifying samples or fuel types are utilized. The Sample Identifiers, shown below in Table E-1, Section E4.1, should be used as the primary sample reference. In figures and tables (where space is limited) and in the text to improve readability, shortened versions of the formal fuel descriptions may appear. For instance, "R8 HRJ" may simply be shortened to "R8" and is assumed to imply a neat fuel. Unless noted otherwise, blends denoted in this manner – "Rentech FT-SPK / JP-8" – are assumed to be 50/50 volumetric blends of the synthetic and petroleum-based fuels. For those blends containing "JP-8" as the petroleum-based fraction, the JP-8 additives are assumed to have been added to the proper levels after the blend was prepared. In some cases, such a blend may be referred to as an "HRJ8" which again implies a 50/50 synthetic / petroleum blend containing JP-8 additives.

Throughout this effort, HRJ or Hydroprocessed Renewable Jet was the favored terminology and is therefore used throughout. The reader should be aware that HEFA or Hydroprocessed Esters and Fatty Acids may appear synonymously with HRJ in other documents.

E3.2 Test Methods

Numerous analytical methods were used in the conduct of this testing. The large majority of those are ASTM "D" and "E" methods. Throughout this document, those methods are simply referenced by their method numbers, *e.g.* "D4052" and "E2716." Non-ASTM methods, such as Federal Test Methods (FTM) and those maintained by SAE, EPA, *etc.* are noted accordingly. Standardized test methods are not discussed at length in this document. These can be acquired from the presiding organizations and some are freely available via the Internet (*e.g.* FTM). Unless noted otherwise, it is assumed that the standardized tests were run as prescribed. New tests, modifications to standardized tests, or non-standardized tests are described in more detail below.

The primary fuel specifications referenced during the conduct of this work are indicated below. Many of these specifications are in flux as they are undergoing extensive modifications to accommodate the new emerging turbine fuels.

ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
MIL-DTL-83133H	Detail Specification: Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37) (30 Apr 2010)
DEF STAN 91-91	Turbine Fuel, Aviation Kerosene Type, Jet A-1, NATO Code: F-35

E3.3 Non-Standard Test Methods

The following sections describe specific methods utilized in this study which were either non-standard or modified in some way to suit the needs of this effort. The reader is referred to a previously published report[1] describing the following alternative/modified methods in detail.

The referenced report lays the groundwork for this effort and provides a good introduction to this topic.

- Hot Surface Ignition Temperature (FTM 791-6053)
- True Vapor Pressure (ASTM D6378)
- Specific Heat Capacity (ASTM E2716)
- Thermal Conductivity (C-Therm TCi Tester)
- Surface Tension (ASTM D1331A)
- Dielectric Constant (SwRI)
- Elastomer (O-ring) Evaluations

E3.3.1 Speed-of-Sound and Isentropic Bulk Modulus

In past efforts, SwRI measured isothermal bulk modulus using an apparatus built according to ASTM D6793. There was some concern that this data was inaccurate based on comparisons to literature data. After reviewing the literature, it was determined that the isentropic bulk modulus is preferred over the isothermal bulk modulus because it relates better to dynamic systems where rapid compression occurs. Isentropic bulk modulus can be calculated using the speed-of-sound and the density of the fluid at a selected temperature and pressure through the following equation:

$$\beta = \rho c^2 \qquad [1]$$

where,

β = isentropic bulk modulus (Pa)

ρ = density (kg/m^3)

c = speed-of-sound (m/s)

Under contract to the U.S. Army, SwRI was tasked to build such as apparatus capable of pressures to 30,000 psi and temperatures to 100°C. At the time of this effort, a prototype cell was available that allowed speed-of-sound measurements at atmospheric pressure. A temperature of 30°C was selected as the temperature nearest to room temperature that could be reliably held constant. The path length of the cell (denoted *d*) was calibrated using reagent grade water at 30°C and atmospheric pressure. Under the same conditions, the speed-of-sound (denoted *c*) for each fuel was measured and calculated as c=2*d/t. The round-trip time of the ultrasonic pulse (denoted *t*) was measured using a digital oscilloscope. Cyclohexane, having a known speed-of-sound of 1228.72 m/s at 30°C, was used as a verification sample and measured several times over the course of the fuel testing. The cyclohexane results were found to have a standard deviation of just 0.54 m/s and a relative error of ≤0.06%. This approach was applied to all fuels studied in this effort.

E3.3.2 Water Solubility vs. Temperature (SwRI)

This test utilizes a standard coulometric Karl Fischer water titrator but the sample preparation is unique. Unaware of any standard procedure to perform this test, SwRI developed the following method and employed it in previous studies. The volumes used in this effort were doubled from previous testing to provide more sample volume for analysis.

- A sample composed of water (2-mL) and fuel (14-mL) are sealed in a 20-mL septum vial.
- The vial is gently shaken and then placed in an oven or cold box and allowed to equilibrate to the test temperature.
- After approximately four hours, the vial is gently shaken again. The vial is then allowed to rest for a period of at least 24 hours at the test temperature.
- After the rest period, a sample is carefully withdrawn through the septum using a syringe without agitating the vial contents. To the extent possible, this is done while maintaining the sample at the test temperature.
- The total water content of the sample is then measured by ASTM D6304.
- Lastly, the temperature of the fuel itself is measured using a thermocouple probe.

E4.0 RESULTS AND DISCUSSIONS

The following sections provide details on specific tasks under this effort. For sub-reports, the reader is directed to the appropriate appendix for further reading.

E4.1 Sample Cross-Reference

The samples in Table E-1 were used during this effort and are discussed at various times throughout the remainder of the document and in sub-documents. The fuels were supplied by AFRL unless noted otherwise. Where available, certificates of Analysis (CofA) are provided in Appendix E-10 (page 385).

Table E-1. Sample Identifiers

POSF#	SwRI CL#	Description
7385	CL10-2127	R8 w/ additives
7386	CL10-2128	50/50 R8/JP-8
7504	CL11-2512	GEVO ATJ
7505	CL11-2513	50/50 GEVO ATJ / JP-8
7066	CL10-1818	Neste Oil NExBTL HRJ
7457	CL11-2185	Rentech FT-SPK
7458	CL11-2183	50/50 Rentech FT-SPK / JP-8
5642	CL09-0268	Sasol FT-IPK
6308	CL10-0773	Tallow HRJ SPK
6152	CL10-0278	Camelina HRJ SPK
5140	CL10-0687	TS-1
6406	CL10-0932	Tallow HRJ SPK/JP-8
6184	CL10-0327	Camelina HRJ SPK/JP-8 (POSF6183/POSF4751)
--	CL11-1623	Shell FT-SPK
--	CL11-2259	JP-8 (SwRI)
--	CL10-0429	Jet A (provided by AFRL for R8 blending)
--	CL11-2413	Premium Ultra-Low Sulfur Diesel
6413	CL10-0796	Opti-Lube Evaluations
6412	CL10-0797	Opti-Lube Evaluations
--	CL10-1266	JP-8 (SwRI)
--	CL10-1986	JP-TS (CLEEN Fuel Program)
--	CL10-1987	JP-5 (CLEEN Fuel Program)
--	CL10-1988	R8 / JP-8 (CLEEN Fuel Program)
--	CL10-1989	JP-8 (CLEEN Fuel Program)
--	CL07-0432	Sasol FT-SPK

E4.2 Evaluation of Synthetic Aviation Fuels

E4.2.1 R8 HRJ

A new sample of R8 HRJ containing JP-8 additives was provided by AFRL. A very limited subset of the FFP testing was performed on this sample targeting lubricity, additive response, safety characteristics, and bulk modulus. The results of these analyses in Table E-3 of Appendix E-1 (page 265). Results from the fuel are also included in the discussion below on critical fuel properties.

E4.2.2 GEVO ATJ

Samples of neat GEVO ATJ (POSF7504, CL12-2512) and a 50/50 GEVO/JP-8 blend (POSF7505, CL12-2513) were provided by AFRL. This batch of GEVO ATJ was prepared from commercially available isobutanol. A partial FFP analysis was performed on the neat GEVO ATJ and the GEVO blend was subjected to a full FFP evaluation. The test results for the neat

GEVO and GEVO/JP-8 blend can be found in Appendix E-2 (page 273). Results from the fuel are also included in the discussion below on critical fuel properties.

The GEVO EPA tests results are also provided in Appendix E-2. The neat GEVO (CL11-2512) contained none of the target compounds specifically sought in the EPA test. Those materials listed with a CAS Number of "TIC" are Tentatively Identified Compounds which have been identified from the mass spectral data alone (i.e., they were not included in the calibration matrix). Those results should be viewed with caution. For the most part, the TICs consist of branched alkanes. The GEVO/JP-8 TICs contain higher molecular weight alkanes. The GEVO/JP-8 sample (CL11-2513) revealed a number of compounds on the target list, although in relatively low concentrations. These compounds primarily consist of a mix of alkanes and aromatics.

Although this fuel is an ATJ and not specifically a hydroprocessed SPK, the distillation slopes are questionable relative to the D7566 specification. These results are similar but slightly lower to the distillation slopes for the Sasol IPK (also highly iso-paraffinic).

E4.2.3 Neste Oil NExBTL HRJ

A sample of NExBTL HRJ (POSF7066, CL10-1818) from Neste Oil was provided by AFRL. Due to limited sample volume, the sample was subjected to a selected set of fit-for-purpose testing. The test results for the NExBTL HRJ can be found in Appendix E-3 (page 312) and includes a full report for the EPA testing. A comparison of results from AFRL on the same fuel is also included in the table. Results from the fuel are included in the discussion below on critical fuel properties.

A value of 94 mg/100 mL for D5304 (Potential Gums) was obtained on the first analysis and is extremely high relative to the D4054 limit of 7 mg/100 mL. Two subsequent re-runs gave values of approximately 11 mg/100 mL which is still a failing value. Confirming AFRL's results, density @ 15°C and viscosity @ -20°C exceed MIL-DTL-83133H specifications.

E4.2.4 Rentech FT-SPK

Samples of neat Rentech FT-SPK (POSF7457, CL11-2185) and a 50/50 Rentech FT-SPK / JP-8 blend (POSF7458, CL11-2183) were provided by AFRL. The neat Rentech FT-SPK contains 1.6 vol% aromatics. A partial FFP analysis was performed on the neat Rentech FT-SPK and the Rentech blend was subjected to a full FFP evaluation. The test results for the neat Rentech FT-SPK and the Rentech FT-SPK / JP-8 blend can be found in Table E-6 of Appendix E-4 (page 336). Results from the fuel are also included in the discussion below on critical fuel properties.

E4.3 Miscellaneous Fuel Testing

Throughout the course of this effort, some requests were made for miscellaneous testing of fuel samples or a study of a selected topic. Work was performed follows:

- Baseline O-ring Testing (Jet A and JP-8)
- Opti-Lube Lubricity Evaluations by HFRR
- Fuel Analysis for the FAA CLEEN Program
- Water Solubility Study
- Speed-of-Sound and Isentropic Bulk Modulus Study

E4.3.1 Baseline O-ring Testing (Jet A and JP-8)

AFRL authorized an elastomer compatibility (O-ring test) analysis of a Jet A (CL10-0429) and JP-8 (CL11-2259) sample to serve as a baseline reference. It should be noted that the JP-8 was not prepared from this Jet A. As in previous testing, three types of O-rings were tested: nitrile, viton, and fluorosilicone. Four replicates of each O-ring were soaked in fuel at room temperature (approximately 22°C) for seven days. Measurements on the O-rings included: volume change, tensile load, and tensile strength. As expected, the results showed these fuels to behave in a nearly identical manner. The volume change results showed that the nitrile material swelled the most while the viton was the least affected.

The test results for the O-ring evaluations can be found in Appendix E-5 (page 374) as follows:

- Jet A Tensile Strength (Figure E-38)
- Jet A Tensile Load (Figure E-39)
- Jet A Volume Change (Figure E-40)
- JP-8 Tensile Strength (Figure E-41)
- JP-8 Tensile Load (Figure E-42)
- JP-8 Volume Change (Figure E-43)

E4.3.2 Opti-Lube XPD Lubricity Evaluations by HFRR

Two fuel samples and a sample of Opti-Lube XPD was provided by WPAFB. The fuel samples had the following designations:

- POSF6413, 56:44 (POSF5698:POSF4765), CL10-0796
- POSF6412, 56:44 (POSF5698:POSF4765) w/ JP-8 additives, CL10-0797

The additive was used to treat selected fuels at a treat rate of 1 part additive to 3000 parts fuel. The selected fuels were then subjected to lubricity evaluation by HFRR (ASTM D6079).

Results from the HFRR testing are shown in Appendix E-6 (page 380), Table E-7. Reference data for typical Jet A and JP-8 samples that had been run recently are included for reference. There are many factors that can affect lubricity, such as sample handling, so the baseline values may vary from sample to sample. Per ASTM D975, all commercial diesel fuel must be below 520 µm. Anecdotal evidence suggests that fuels are often over-treated to help maintain that lubricity so a result of 450-500 µm is not uncommon for diesel fuel.

An initial observation was that the test results for the POSF 6412 and 6413 were backward from the original analysis done in May 2010. These suspicious results suggested that the samples or data were swapped at one point or another. So the base fuels were re-run again making sure to sample them correctly. The re-runs seem to be in agreement with the newer data but since the repeatability (and reproducibility) of the method can be relatively high it is difficult to be certain. However, it does appear that the Opti-Lube has no significant effect on the lubricity as far as HFRR is concerned. We often see that HFRR is not very responsive to additive treatment. The BOCLE test, ASTM D5001, is usually more sensitive to additive treatment and is often used to gauge additive efficacy.

E4.3.3 Fuel Analysis for the FAA CLEEN Program

AFRL agreed to support the Federal Aviation Administration's (FAA) CLEEN program by analyzing samples for Rolls-Royce Liberty Works. Four samples were received for analysis per

ASTM D1655 and other miscellaneous tests. The four samples consisted of a JP-8, JP-5, JP-TS, and a 50/50 R8/JP-8 blend. The test results for the CLEEN fuels can be found in Table E-8 of Appendix E-7 (page 381).

The JP-TS sample showed a high existent gum content (20 mg/100 mL) and the R8/JP-8 had a high electrical conductivity (1053 pS/m).

E4.3.4 Water Solubility Study

AFRL authorized a study on water solubility at several temperatures for various fuels. Blends (50/50) of synthetic fuel and petroleum-derived fuel were prepared using a single Jet A for commonality. Clay-treated HRJ fuels were also included in the study to determine if clay-treating has any impact on the ability of the HRJ fuels to hold water. Target test temperatures for the study ranged from approximately -10 to 50°C.

The fuel test matrix was as follows:

- Camelina HRJ, POSF6152, CL10-0278
- Tallow HRJ, POSF6308, CL10-0773
- Camelina HRJ-CT (clay-treated), CL11-2250
- Tallow HRJ-CT (clay-treated), CL11-2251
- Shell FT SPK, CL11-1623
- Sasol FT SPK, CL07-0432
- Jet A, CL10-0429
- 50/50 Camelina HRJ / Jet A, CL11-2252
- 50/50 Tallow HRJ / Jet A, CL11-2253
- 50/50 Camelina HRJ-CT / Jet A, CL11-2254
- 50/50 Tallow HRJ-CT / Jet A, CL11-2255
- 50/50 Shell FT-SPK / Jet A, CL11-2256
- 50/50 Sasol FT-SPK / Jet A, CL11-2257

The tabulated test results for the water solubility study can be found in Table E-9 of Appendix E-8 (page 383). Generally, it was observed that in some cases clay-treating the neat fuel resulted in a small reduction in the amount of retained water. However, in most cases, subsequent blending with Jet A gave similar results to non-clay-treated fuel. The overall result, as seen in this report and previous work, is that some of the alternative fuels have a stronger affinity for water. It's unclear if this is related to the additives in the fuel or the composition of the fuel or both. We noted that some fuels respond differently to additives. Perhaps there's a relationship between additive efficacy and water retention that's connected to the composition of the fuel. An example of this may be the Neste HRJ where we've noted its poor response to additive treatment coupled with its low water retention.

E4.3.5 Speed-of-Sound and Isentropic Bulk Modulus Study

AFRL authorized a study on Speed-of-Sound and Isentropic Bulk Modulus. Utilizing the U.S. Army's prototype apparatus, SwRI began to build a library of speed-of-sound and isentropic bulk modulus data for a large set of fuels provided by the Air Force. The fuels analyzed under this study were as follows:

- R8 w/ JP-8 additives
- 50/50 R8 / JP-8
- Sasol IPK
- Neste Oil NExBTL HRJ
- 50/50 Rentech FT-SPK / JP-8
- Rentech FT SPK w/ JP-8 additives
- Tallow HRJ
- Camelina HRJ
- TS-1
- 50/50 Tallow HRJ / JP-8
- 50/50 Camelina HRJ / JP-8
- Shell FT SPK
- JP-8
- Jet A
- Premium ULSD
- GEVO ATJ
- 50/50 GEVO ATJ / JP-8

The results for this study can be found in Table E-10 of Appendix E-9 (page 384). When sorted as a function of bulk modulus, the expected trend among the fuels emerges. Generally, the fuels are arranged in order of bulk modulus as follows:

diesel fuel > neat petroleum-derived jet fuel > 50/50 blends > neat alternative jet fuel

The highly isomerized fuels like Sasol IPK and GEVO ATJ tend to have the lowest bulk modulus. The only input to date from the OEMs is that bulk modulus needs to be > 100k psi. Clearly, all of these fuels meet that requirement. Based on the findings thus far, there is sufficient evidence to conclude that the isothermal bulk modulus data reported previously is biased high. Given the accuracy of the cyclohexane speed-of-sound verification runs and the accuracy with which density is normally measured, there is every reason to believe that the isentropic bulk modulus data is more accurate.

E4.4 Discussion of Selected Fuel Properties

This section contains a discussion of selected fuel properties with particular focus on the flight-critical fuel properties. Where possible, fuels evaluated during this study are compared with expected values for petroleum-derived fuels based on historical data (CRC Handbook of Aviation Fuel Properties[2], CRC World Fuel Sampling Program[3]). This serves to highlight some of the distinct characteristics inherent to some of the fuels and illustrate the expected extremes that may be encountered when dealing with the emerging synthetic fuels.

E4.4.1 Distillation (D86)

Distillation values for selected fuels in this study are shown in Figure E-1 and illustrate the uniqueness of some of these alternative fuels. Related to its narrow composition range, the GEVO fuels have much flatter distillation curves. This results in lower than expected values for the distillation slopes relative to D7566. The Neste fuel, being entirely paraffinic, has a much higher boiling point curve than any other fuel in this study. The Rentech fuels appear to be the most similar relative to the expected Jet A values. This data seems to corroborate other volatility-related measurements such as vapor pressure.

E4.4.2 True Vapor Pressure (D6378 Triple Expansion)

Results for true vapor pressure by the triple expansion method are shown in Figure E-2. These samples were all measured in the unattended operation mode of the Eravap Vapor Pressure Tester (Eralytics) from 0-120°C with 10°C increments. The SwRI Jet A generally agrees with the CRC Aviation Handbook data (determined by calculation from Reid vapor pressures). The alternative fuels generally exhibit higher vapor pressures but are still within the upper bounds of the results obtained for a TS-1. This suggests that the alternative fuels and blends might exhibit similar behavior to fuels already approved and in everyday use.

E4.4.3 Density (D4052)

Density values for the test fuels are shown in Figure E-3. There is good agreement between SwRI's Jet A and the CRC Aviation Handbook Jet A data. The alternative fuel blends appear to cluster tightly and fall within the specification limits as stated in D7566. The neat fuels, including the Neste HRJ, fall outside of the specification limits and therefore require blending to bring them into specification. The low densities for the neat fuels are related directly to the lack of aromatics.

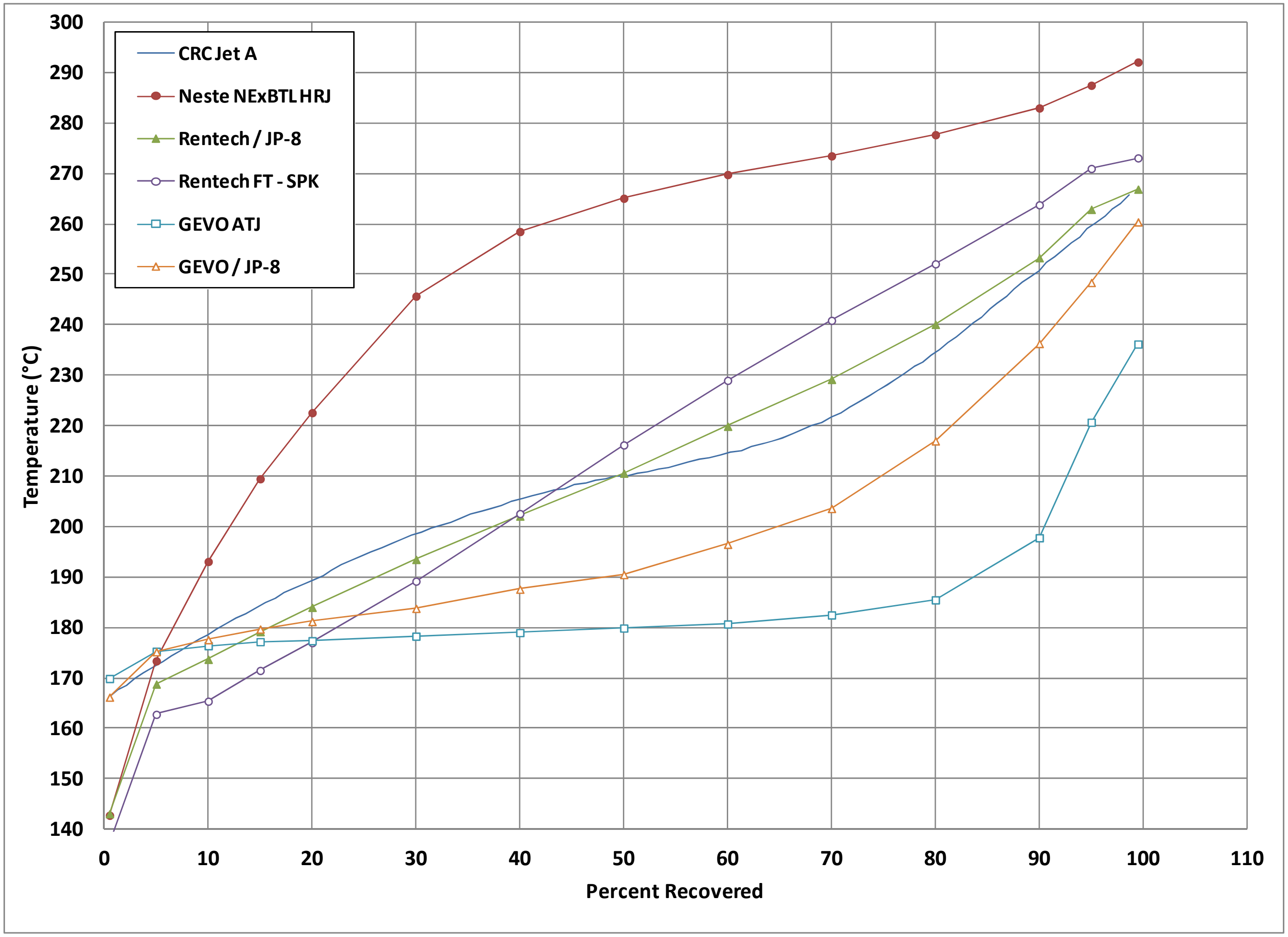

Figure E-1. Distillation (D86)

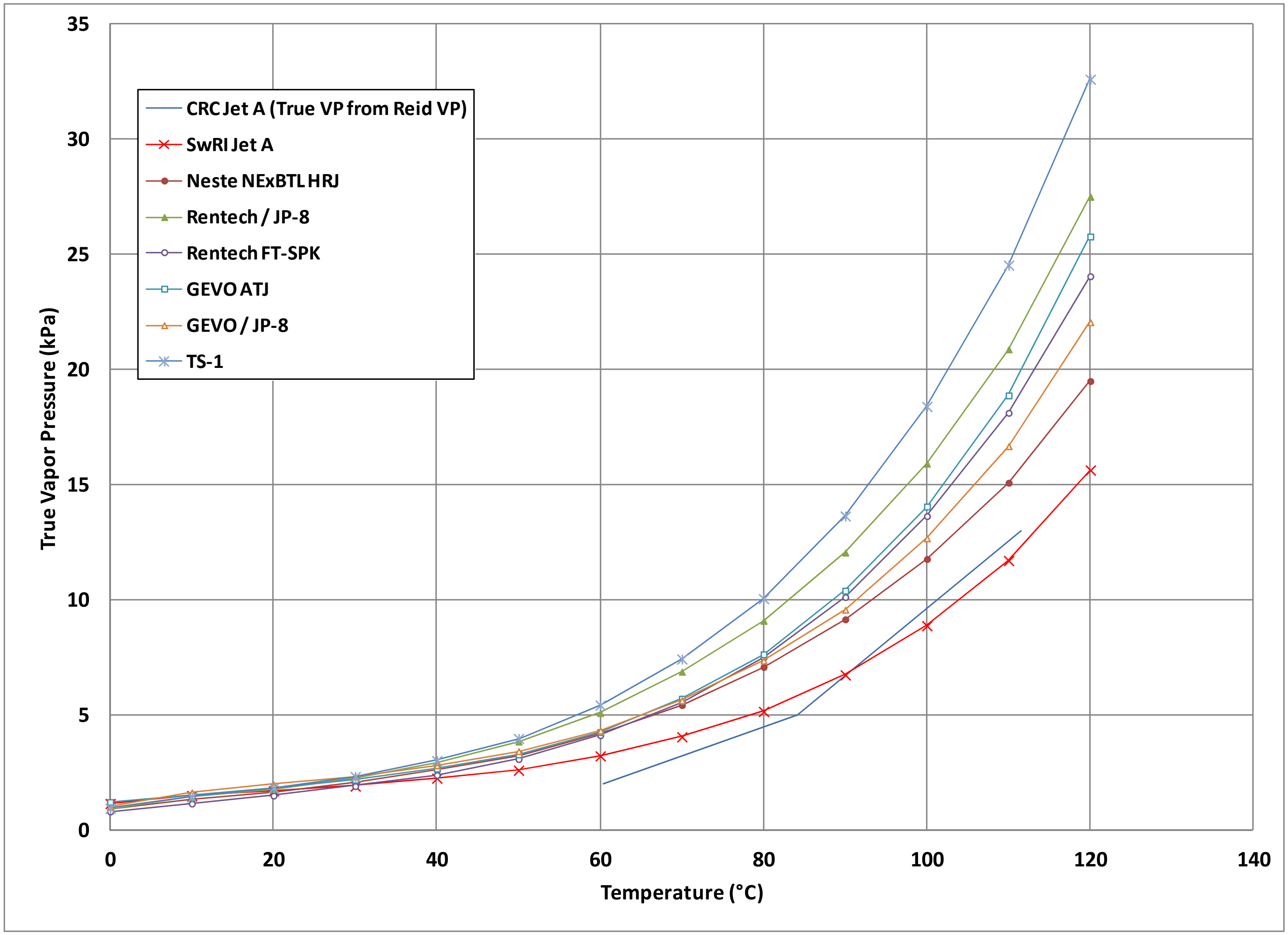

Figure E-2. True Vapor Pressure (D6378)

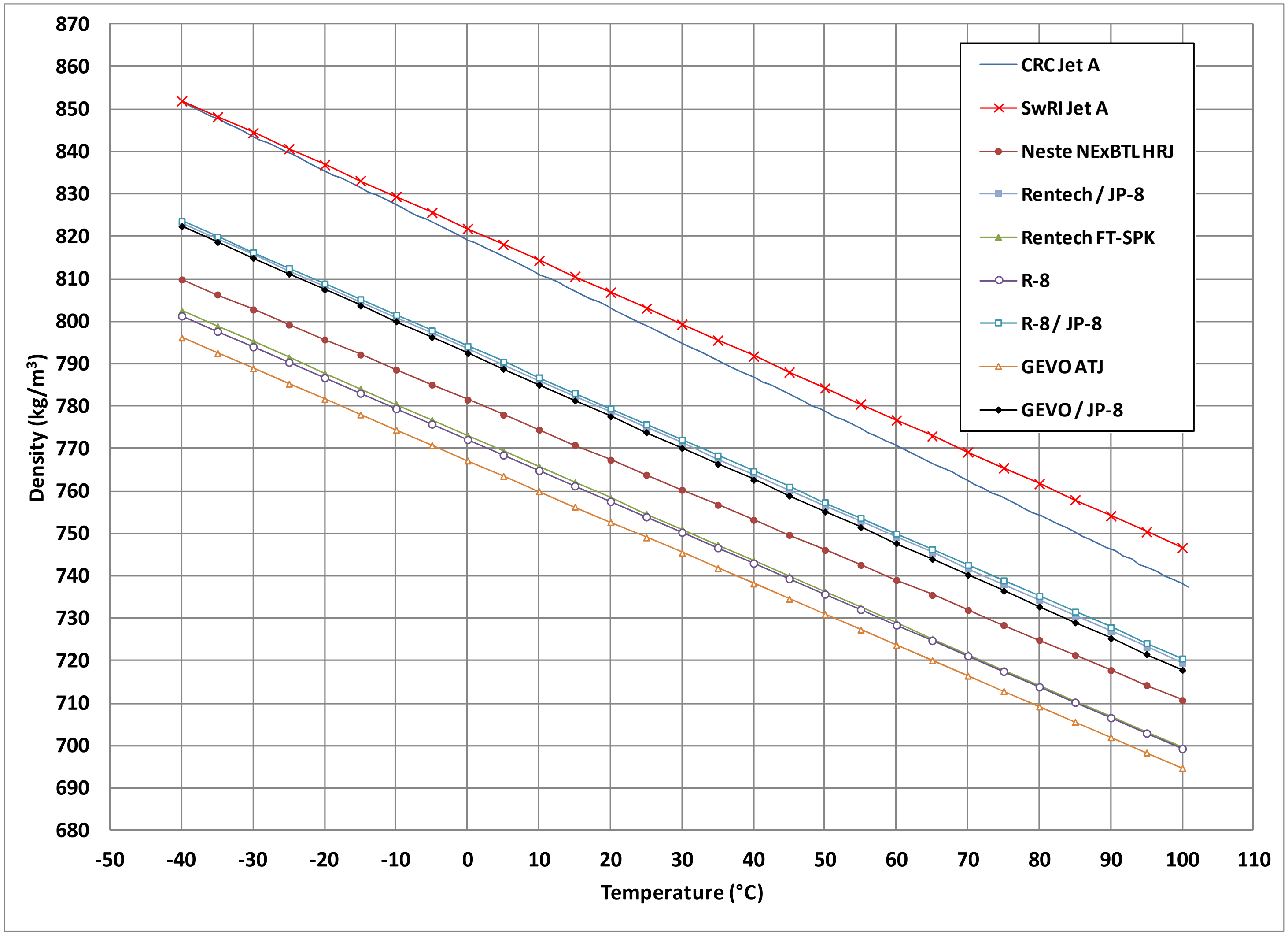

Figure E-3. Density (D4052)

E4.4.4 Dielectric Constant

Dielectric constant varies inversely as a function of temperature and shows distinguishable differences between fuel types (Figure E-4). The fuels tend to cluster according to composition: neat alternative fuel < blends < neat petroleum-derived fuels. Relative to density (Figure E-5), the differences appear to be minimal. This would suggest that the alternative fuels would behave in a similar manner to petroleum-derived fuels with regard to capacitive-based tank gauging systems.

This data was generated by measuring the dielectric constant at a series of temperatures between -40°C and 80°C. The density at these temperatures was determined by extrapolation from the density curves for the particular fuel. A linear curve fit of the corresponding data allowed the dielectric constant to be plotted across a range of densities or temperatures. This data was generated at a frequency of 10kHz. The CRC and Word Survey data were likely collected at much lower frequencies (e.g. 400Hz). In previous efforts, testing performed at frequencies up to 12 kHz showed no significant effect on dielectric constant. This may not be true for all dielectric cells and fuels containing excessive water.

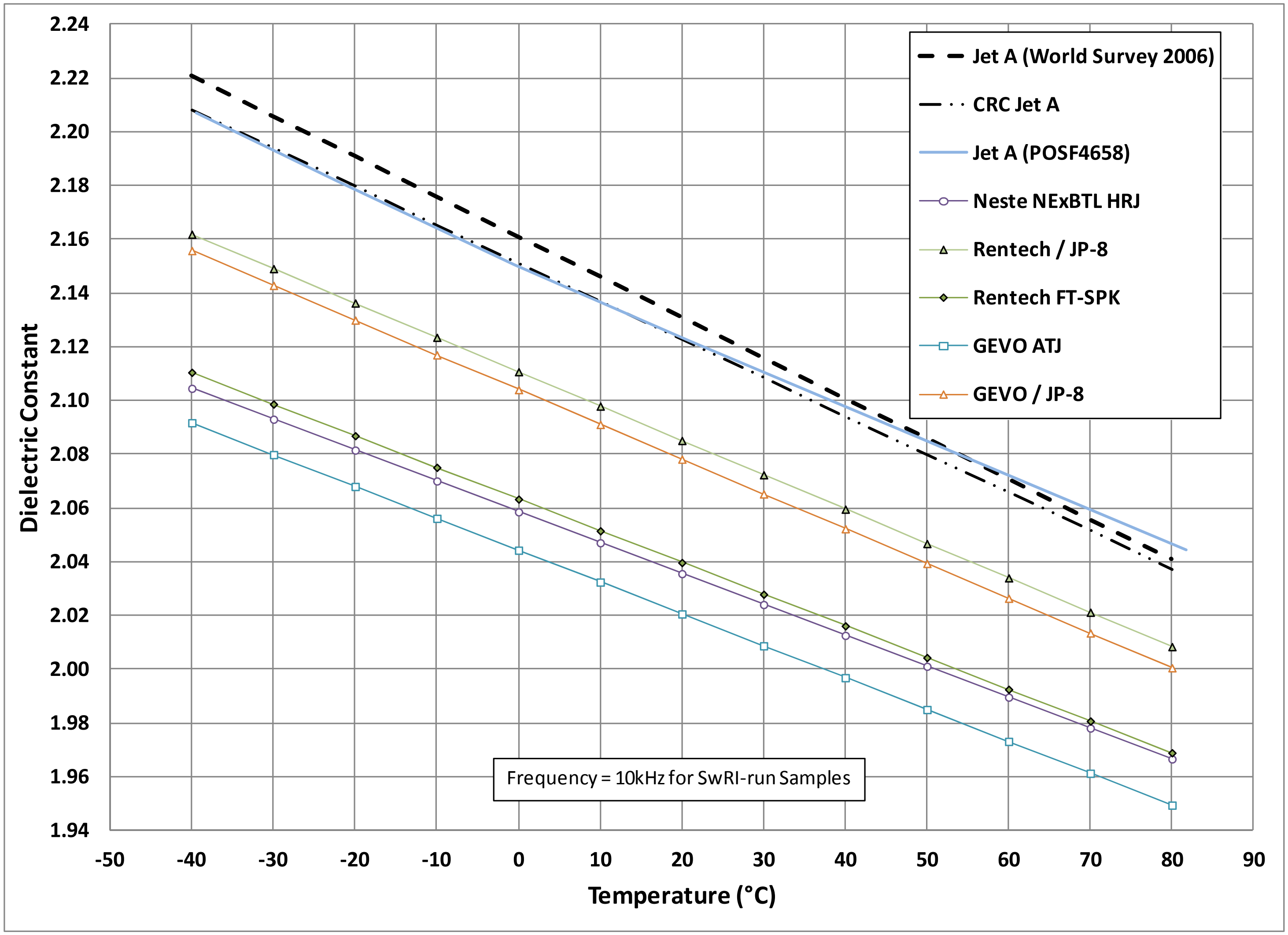

Figure E-4. Dielectric Constant vs. Temperature

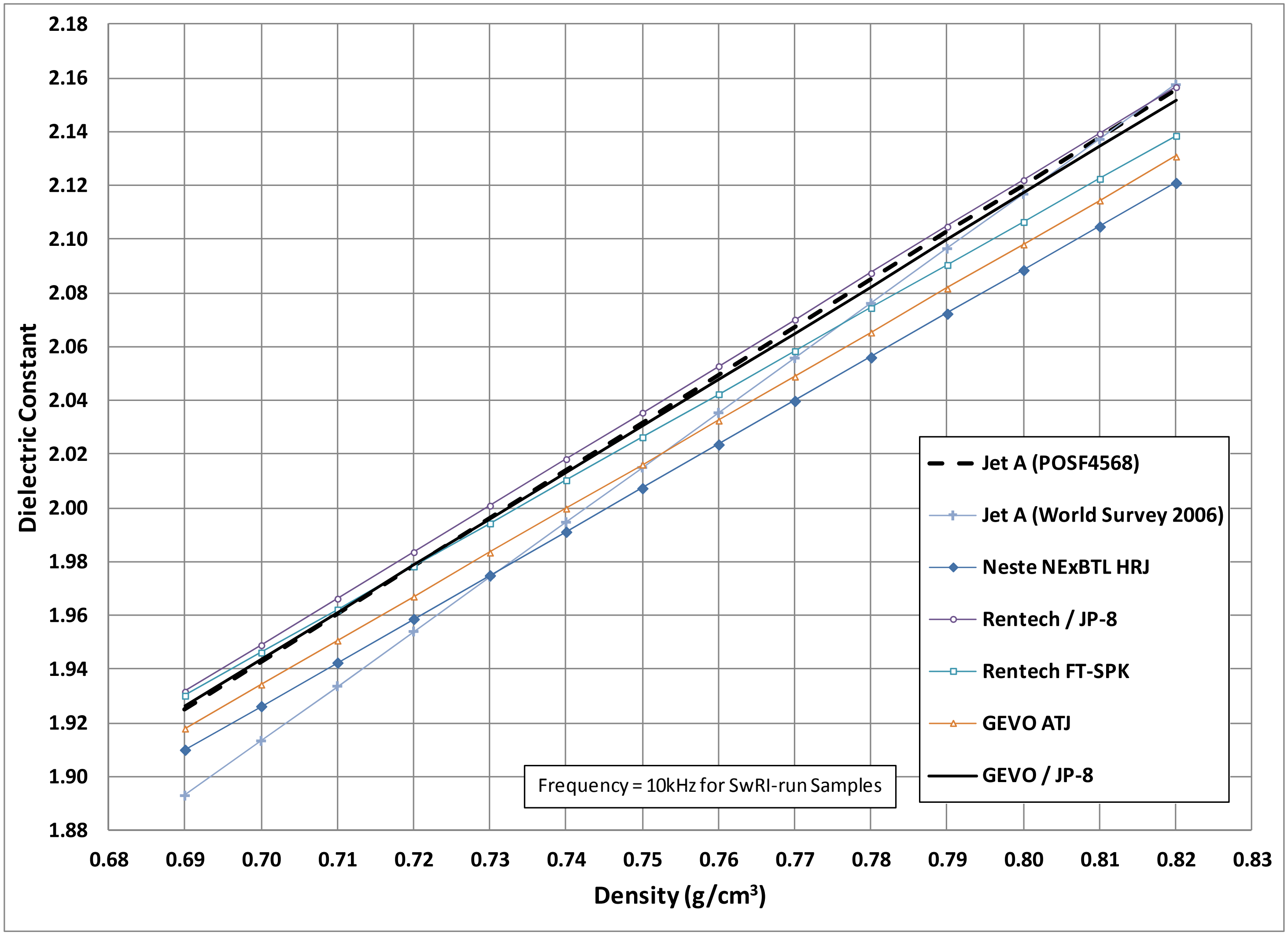

Figure E-5. Dielectric Constant vs. Density

E4.4.5 Spontaneous Ignition

The CRC Aviation Handbook lists two general types of spontaneous ignition: Autoignition and Hot Surface Ignition.

E4.4.5.1 Autoignition Temperature (ASTM E659)

The Hot Flame Autoignition Temperature (AIT), determined by ASTM E659, is the temperature at which fuel vapor will ignite in the absence of an ignition source. AIT values for typical hydrocarbon fuels are expected to fall between 200-260°C. Two fuels in this study fell just beyond these limits (Figure E-6). The Neste HRJ fell just short of the lower limit and the Rentech blend slightly above it. This test is primarily safety related and the data suggests that these fuels would not likely pose any greater threat than a petroleum-derived fuel.

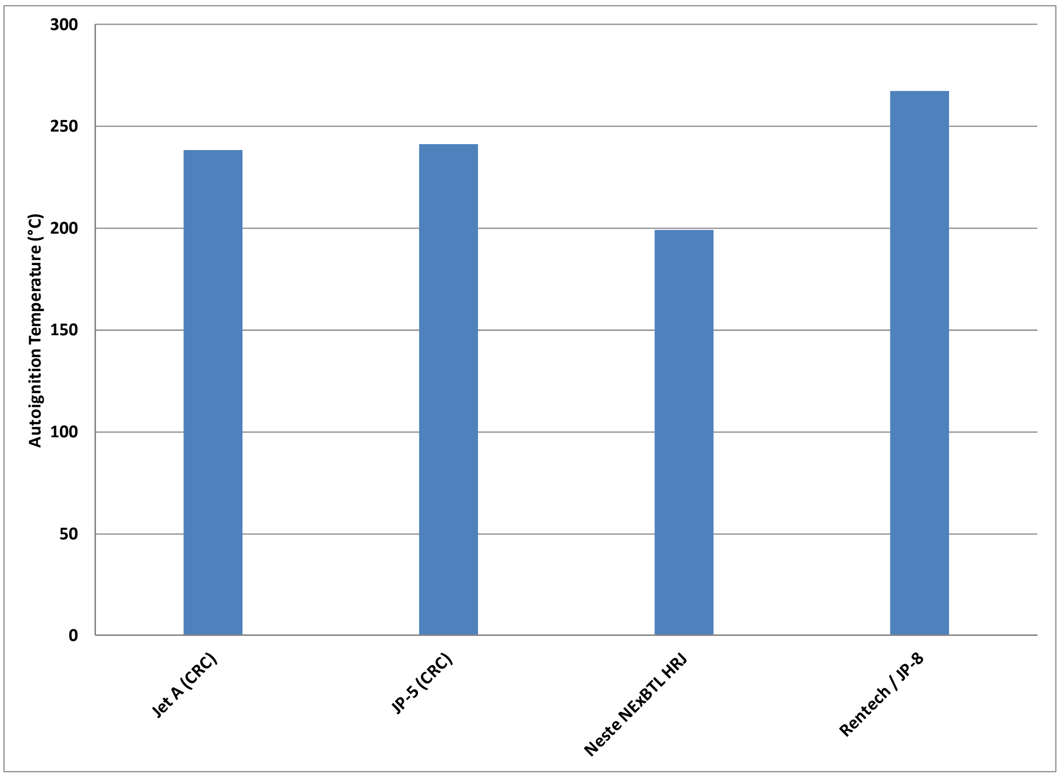

Figure E-6. Autoignition Temperature

E4.4.5.2 Hot Surface Ignition Temperature (FTM 791-6053)

The Hot Surface Ignition Temperature (HSIT) is measured according to Fed-Std-791 (6053). In the standard form of this test, the fuel is dripped onto a heated manifold at 1300°F. The purpose of this test is simply to determine whether the fuel burns or not at that temperature. There are no pass/fail criteria. SwRI runs a slightly modified procedure by attempting to bracket the actual ignition temperature. Expected values for HSIT are 800-1200°F. Of the fuels tested in this study (Figure E-7), only the Neste HRJ gave results slightly higher than expected. This seems to coincide with its other unique volatility characteristics like its high boiling points and low vapor pressure.

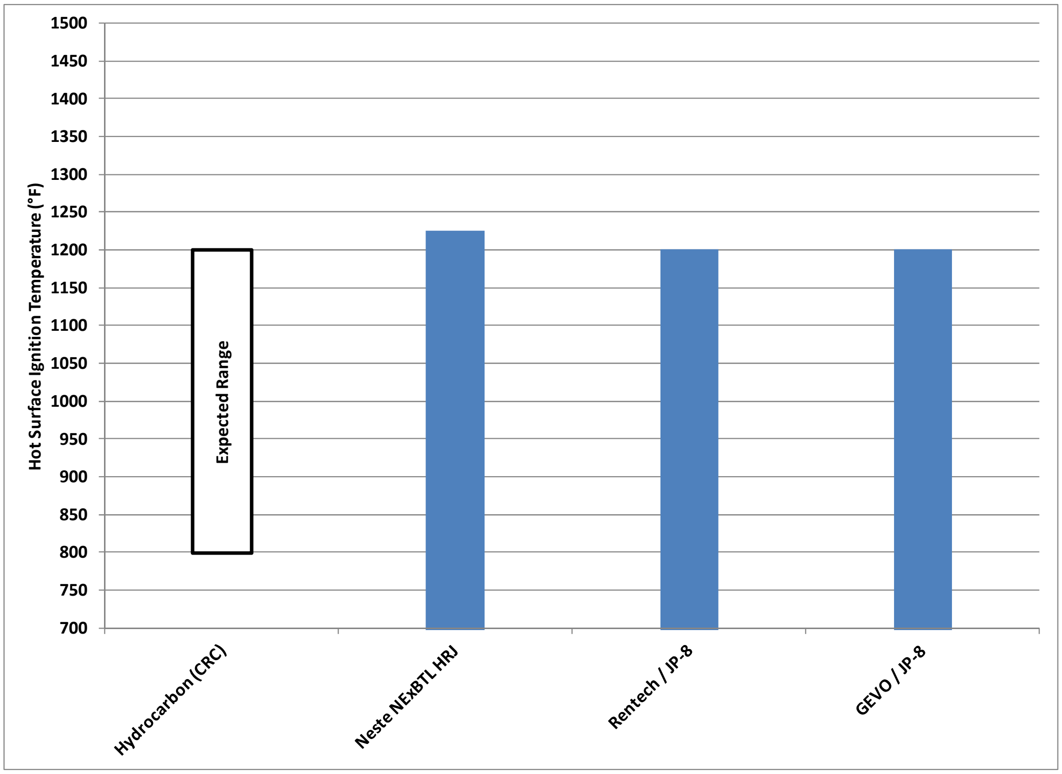

Figure E-7. Hot Surface Ignition Temperature

E4.4.6 Minimum Ignition Energy (ASTM E582)

This test measures the minimum amount of energy necessary to ignite a hydrocarbon fuel/air mixture. The energy is provided via a spark discharge and is expected to fall in the range of 0.2 to 1.0 mJ. The fuels tested in this study, Figure E-8, fell within the expected range. In order to create the fuel/air mixture, the fuel had to be heated to get complete vaporization. A temperature of 100°C was the standard temperature employed.

E4.4.7 Upper/Lower Explosion Limits (ASTM E681)

Like the minimum ignition energy test, testing for the upper/lower explosion limits require the fuel to be vaporized by heating. A temperature of 100°C was used here also to vaporize the samples. Of the fuels tested by this method, Figure E-9, the lower explosion limits ranged from 0.3-0.4 vol% and the upper explosion limit ranged from 3.9-6.1 vol%. The nominally expected values were 0.6 and 4.7 vol%, respectively. The GEVO / JP-8 blend was somewhat lower than the other fuels in this study. We can only surmise that this is related to its comparatively flat distillation curve and more uniform composition.

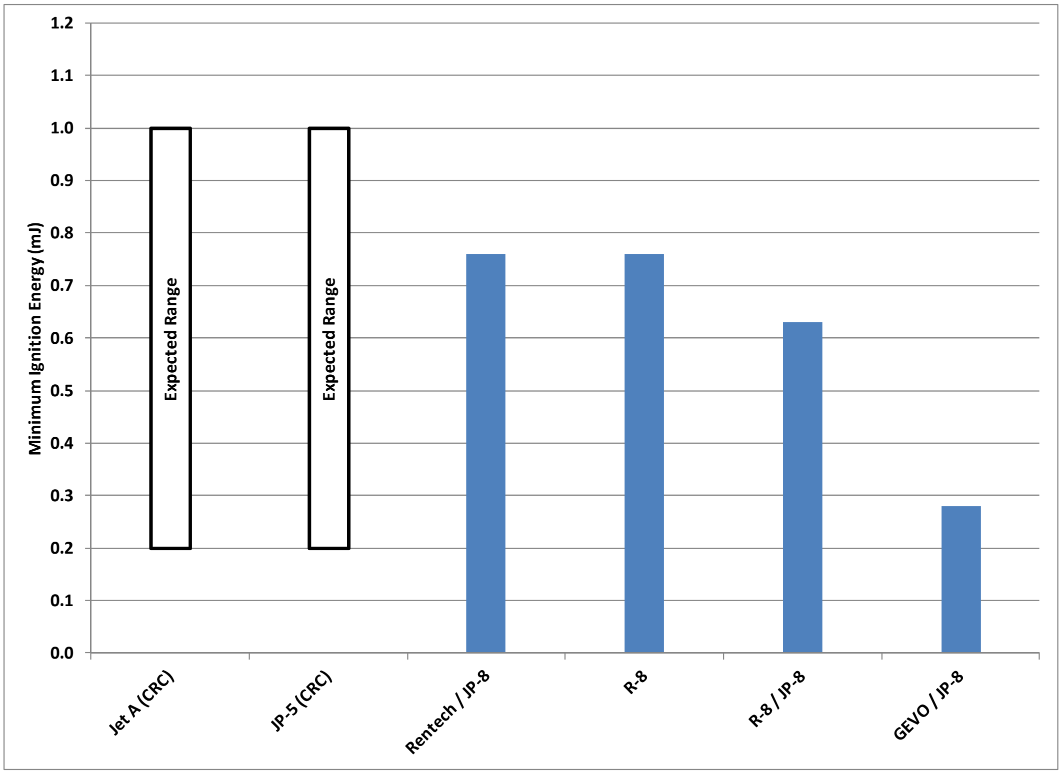

Figure E-8. Minimum Ignition Energy

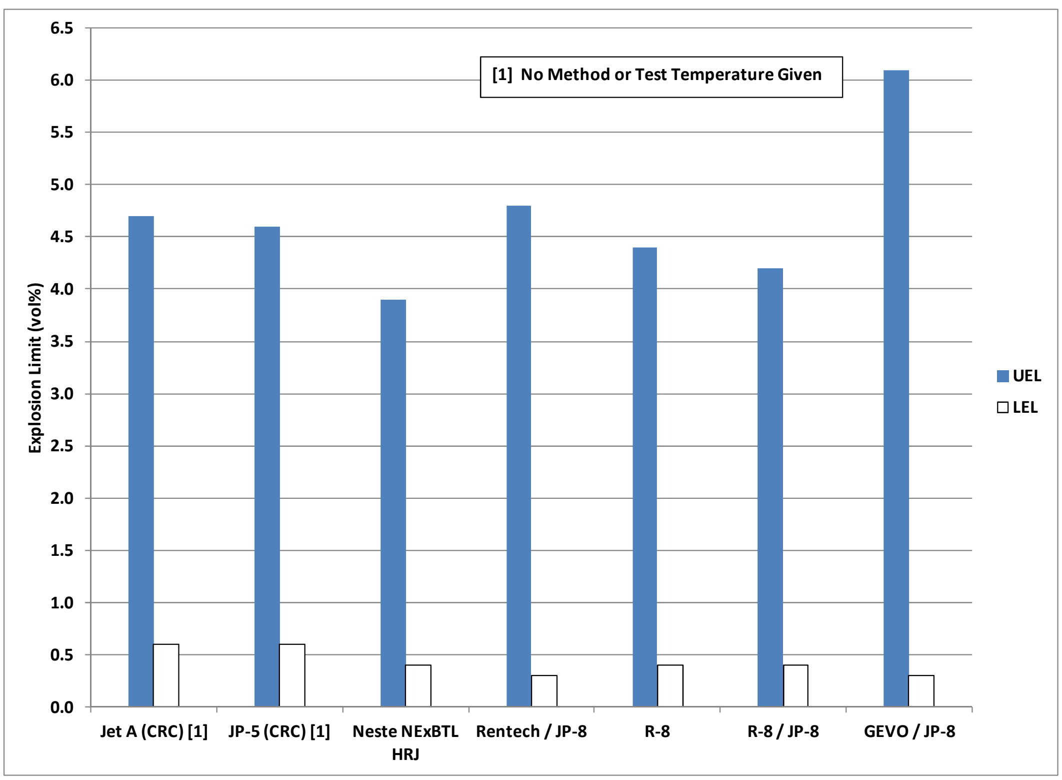

Figure E-9. Explosion Limits

E4.4.8 Specific Heat Capacity (E2716)

The reversing heat capacity results are shown in Table E-2 and plotted in Figure E-10. Consistent with other unusual data, the heat capacity of the Neste HRJ was found to be significantly higher than the other fuels in this study and fuels in general.

Table E-2. Reversing Heat Capacity

SwRI Sample ID	Reversing Heat Capacity (kJ/kg.K)					Equation
	-30°C	0°C	50°C	100°C	150°C	
CL11-2513 (GEVO / JP-8)	1.658	1.775	1.969	2.163	2.357	Cp = 0.0039*T + 1.7749
CL10-1818 (Neste HRJ)	2.137	2.237	2.403	2.570	2.737	Cp = 0.0033*T + 2.2366
CL11-2183 (Rentech / JP-8)	1.693	1.799	1.977	2.155	2.333	Cp = 0.0036*T + 1.7995

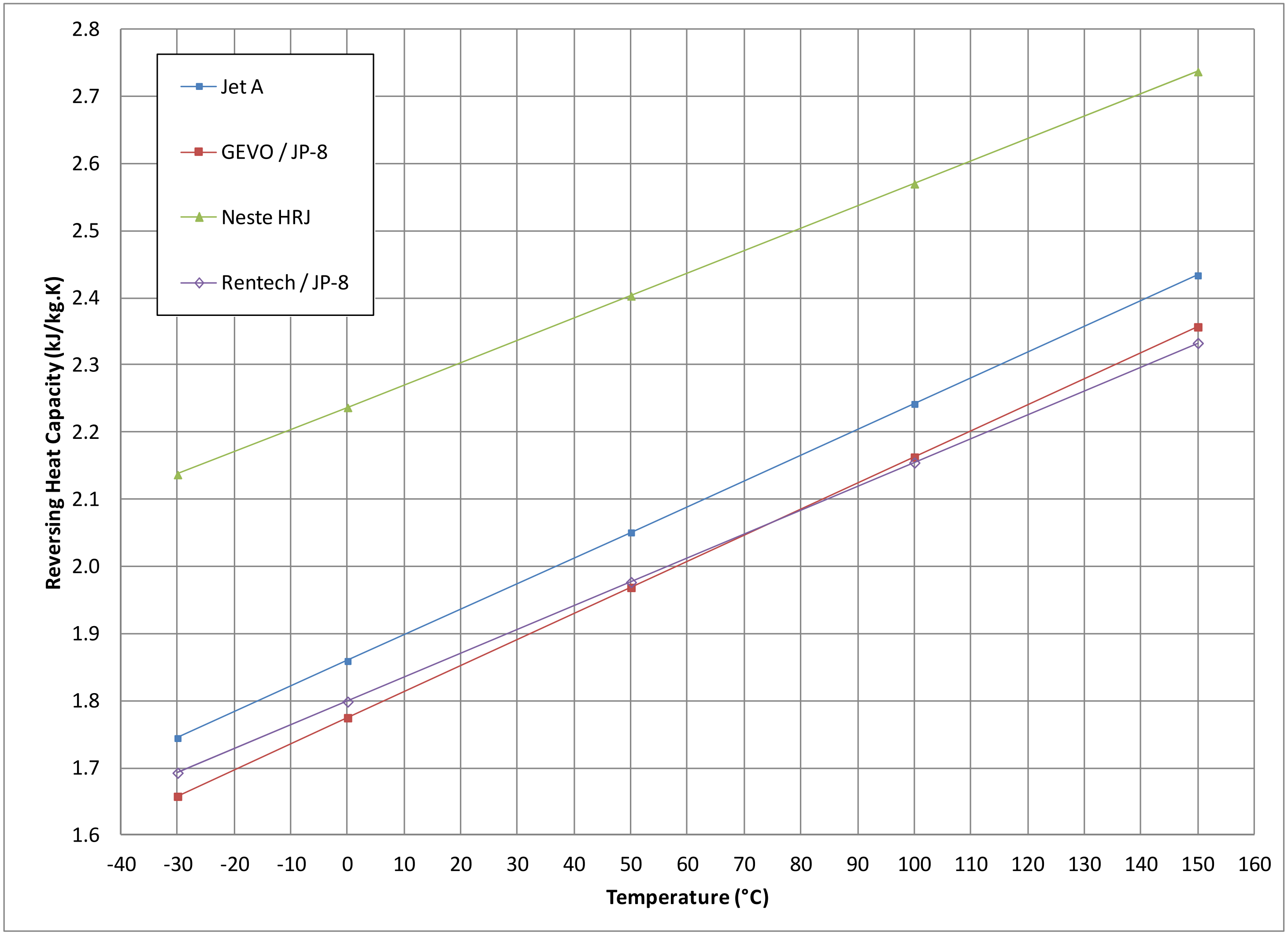

Figure E-10. Reversing Heat Capacity

E4.4.9 Thermal Conductivity (Modified Transient Plane Source)

Based on data reported by the CRC Aviation Handbook and NIST**, the expected thermal conductivity values for a typical aviation fuel might be expected to fall in the range of 0.9-0.14 W/m.K. The CRC data shown in Figure E-11 was measured by the hot-wire technique. The other results are calculated from effusivity values obtained from a TCi tester (C-Therm Technologies). This difference between the two methods was not unexpected. Since these fuels are all hydrocarbon in nature, it is expected that their thermal conductivities will be similar. For the most part, these fuels tend to cluster around the Jet A. The Rentech blend gave slightly higher values.

E4.4.10 Surface Tension (D1331A)

From a practical application standpoint, surface tension is primarily affected by temperature and the presence of surfactants. An increase in temperature or the addition of surfactants generally causes a decrease in the surface tension of the fuel. Surface tension implies that the fuel is in direct contact with air. From a performance standpoint, the surface tension can affect fuel atomization.

For selected fuels in this study, the surface tension as a function of temperature is shown in Figure E-12 and is in generally good agreement with the CRC Aviation Handbook values. The values would suggest that these fuels would have fuel/water separation characteristics similar to Jet A; however, that can be highly dependent on the type of additives present.

**Data provided by AFRL but withheld from this report.

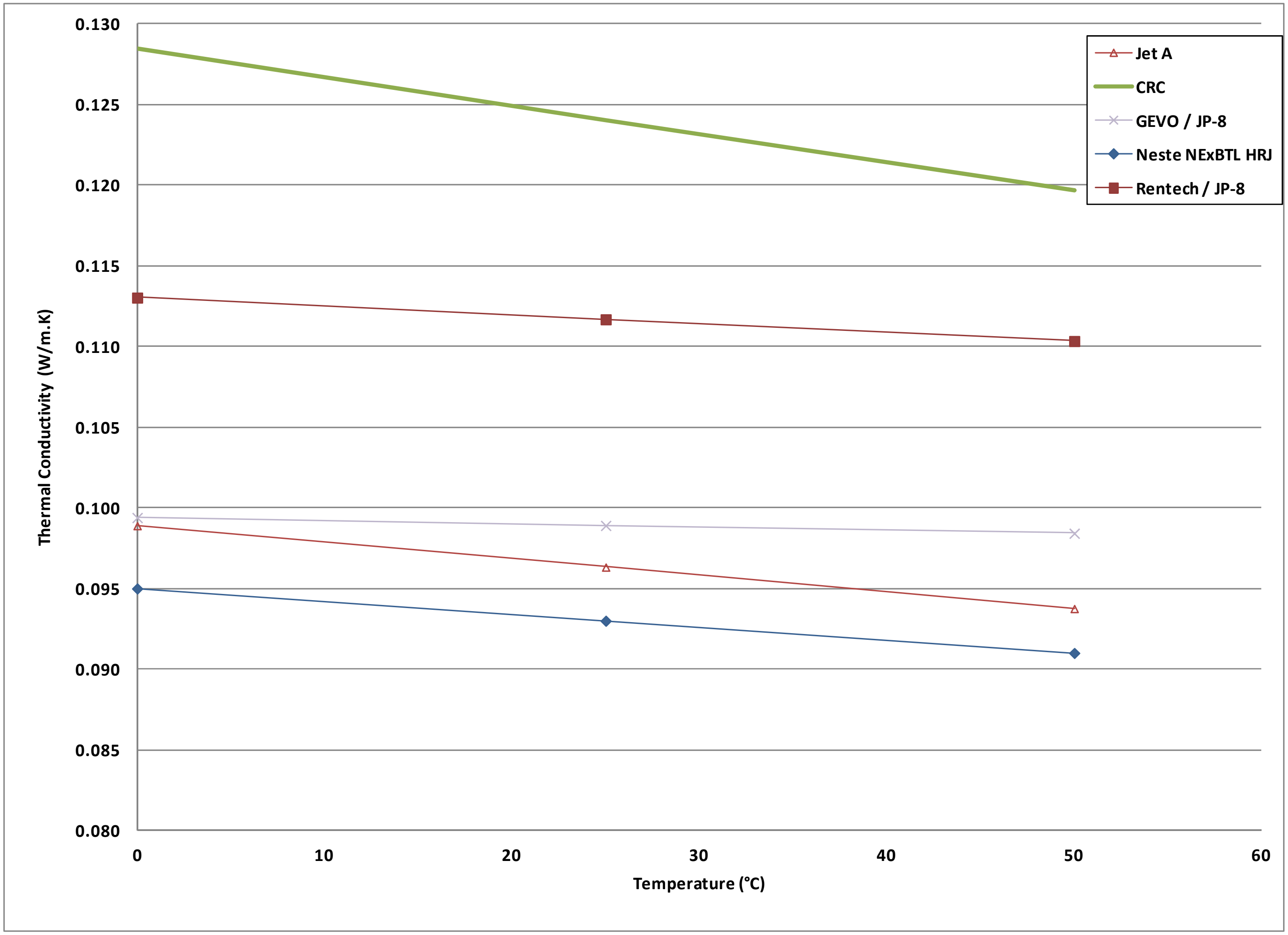

Figure E-11. Thermal Conductivity

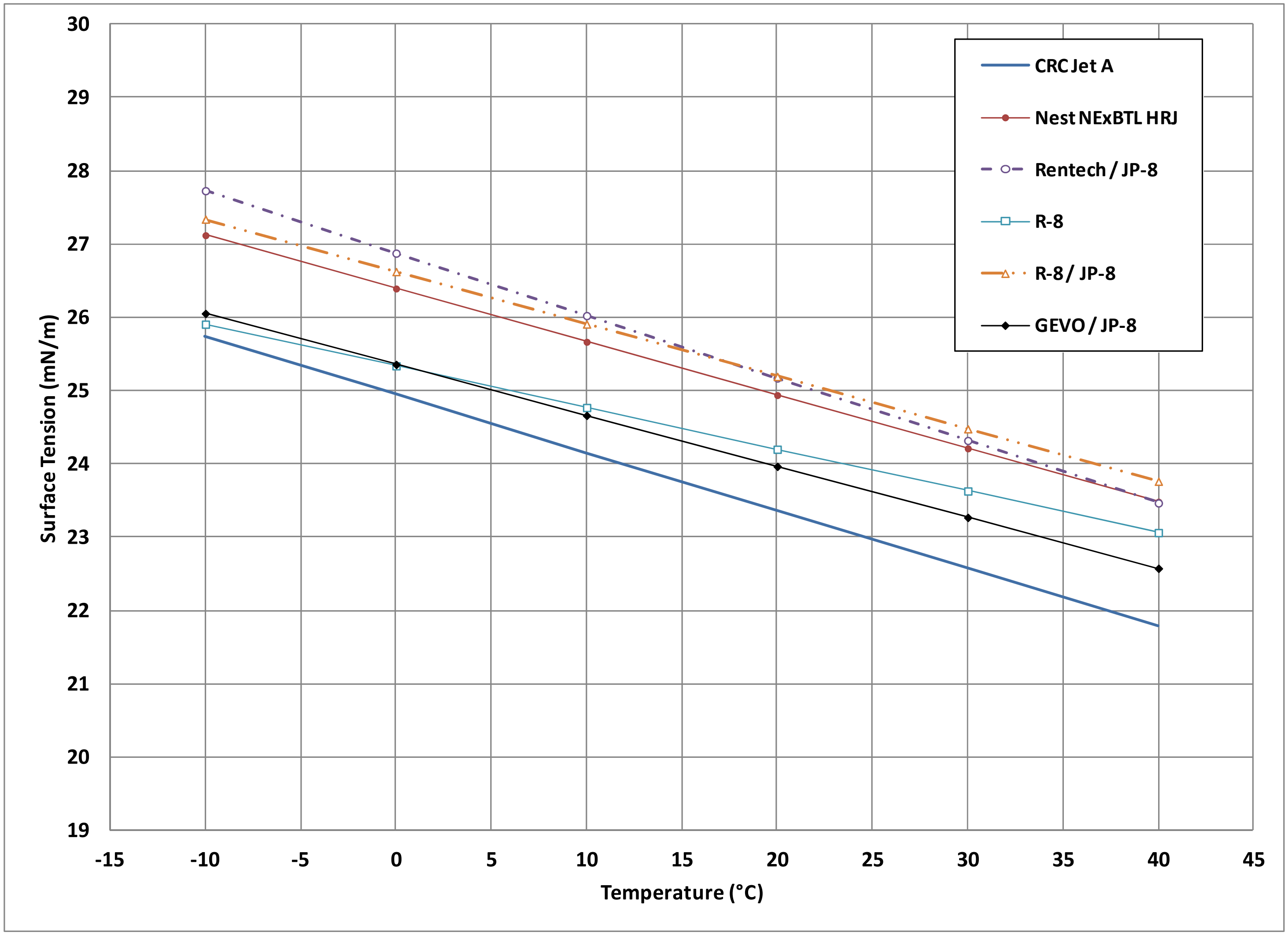

Figure E-12. Surface Tension (D1331A) vs. Temperature

E4.4.11 BOCLE (D5001) vs. CI/LI Concentration (DCI-4A)

A standard BOCLE test of neat fuel provides an indication of the inherent lubricity of the fuel. Equally important is to determine the response of a unadditized fuel to the addition of a standard lubricity improver (DCI-4A). Prior to testing, the selected fuels are clay-treated to remove all additives. The fuels are then re-additized and their lubricity re-evaluated. The general finding is that most fuels respond immediately to low dosages of additive. When clay-treated, some of these fuels exhibit extremely poor lubricity (Figure E-13). However, even at low dosages of DCI-4A (10 mg/L) the lubricity of most of the fuels dropped below 0.85 mm. The GEVO fuels appeared to be the "hardest" with respect to lubricity. The Rentech fuels had decent lubricity even after clay-treating. The Neste HRJ had unusually good lubricity and did not respond to additive treatment. In general, for an added level of protection it would be advisable to additize these all fuels when used in equipment sensitivity to lubricity such ground vehicles.

E4.4.12 Water Content (D6304) vs. Temperature

The results for the water solubility test are shown in Figure E-14. The slopes of the water solubility curves are generally in good agreement with the CRC data. Some fuels show a slight predilection for water over others. This could be due to the additives present in the fuel or the composition of the fuel itself. Interestingly, all of these fuels had poor MSEP values except the Neste HRJ which also showed little ability to hold water.

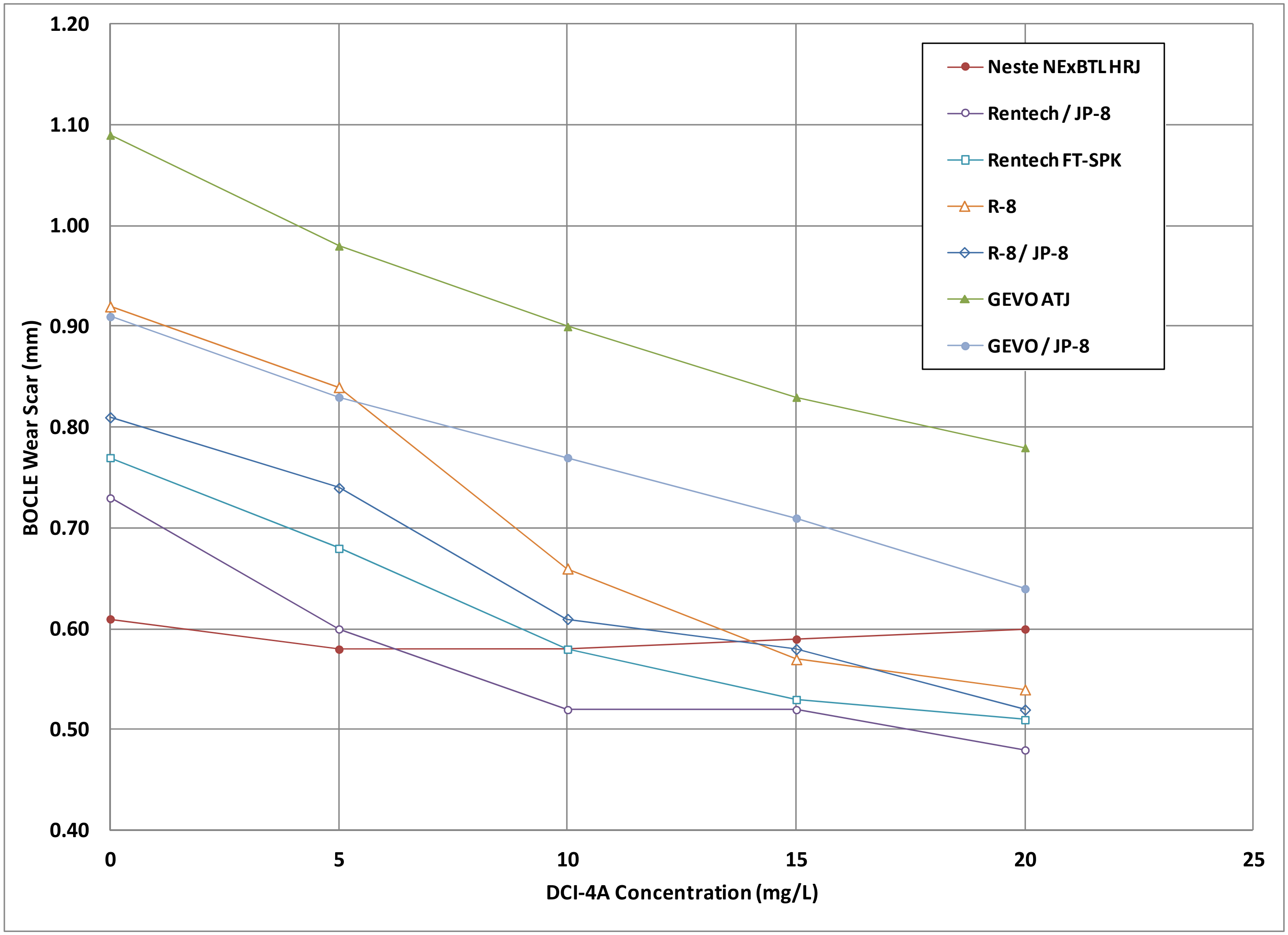

Figure E-13. BOCLE (D5001) vs. CI/LI Concentration (DCI-4A)

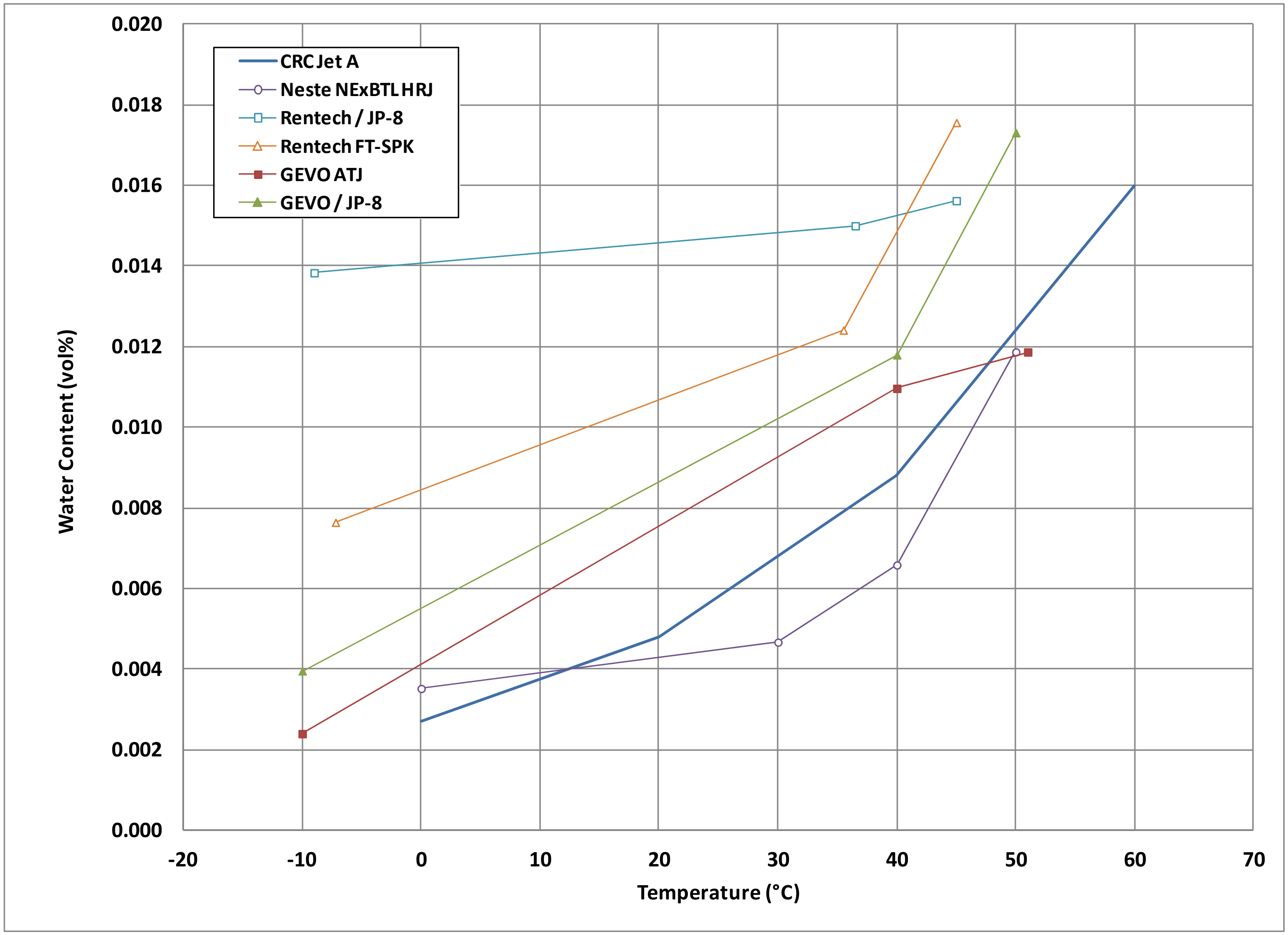

Figure E-14. Water Content (D6304) vs. Temperature

E4.4.13 Kinematic Viscosity (D445)

Kinematic viscosity data for selected fuels are shown in Figure E-15. The GEVO fuels show good agreement to the CRC Aviation Handbook Jet A data. The Neste HRJ was significantly more viscous than other fuels.

E4.4.14 Electrical Conductivity (D2624) vs. SDA Concentration (Stadis 450)

Understanding how a fuel responds to the addition of static dissipator additive (SDA) is critical to prevent over or under-additizing in the field. Procedurally similar to the lubricity evaluation, the fuel is first clay-treated and then dosed with varying amount of Stadis 450. The electrical conductivity is then measured at room temperature using a hand-held meter. A comparison of fuels in this effort is shown in Figure E-16. Like the lubricity evaluation, the Neste HRJ did not respond well to additive treatment. The GEVO fuels also showed a weaker response. The Rentech fuels gave a good response to treatment similar to the lubricity evaluation.

E4.4.15 Electrical Conductivity vs. Temperature

Electrical conductivity as a function of temperature is shown in Figure E-17. Following other trends seen thus far, the Rentech fuel responded to the increased temperature with an increase in electrical conductivity. The Neste HRJ stayed relatively flat throughout the test for all but the highest temperatures.

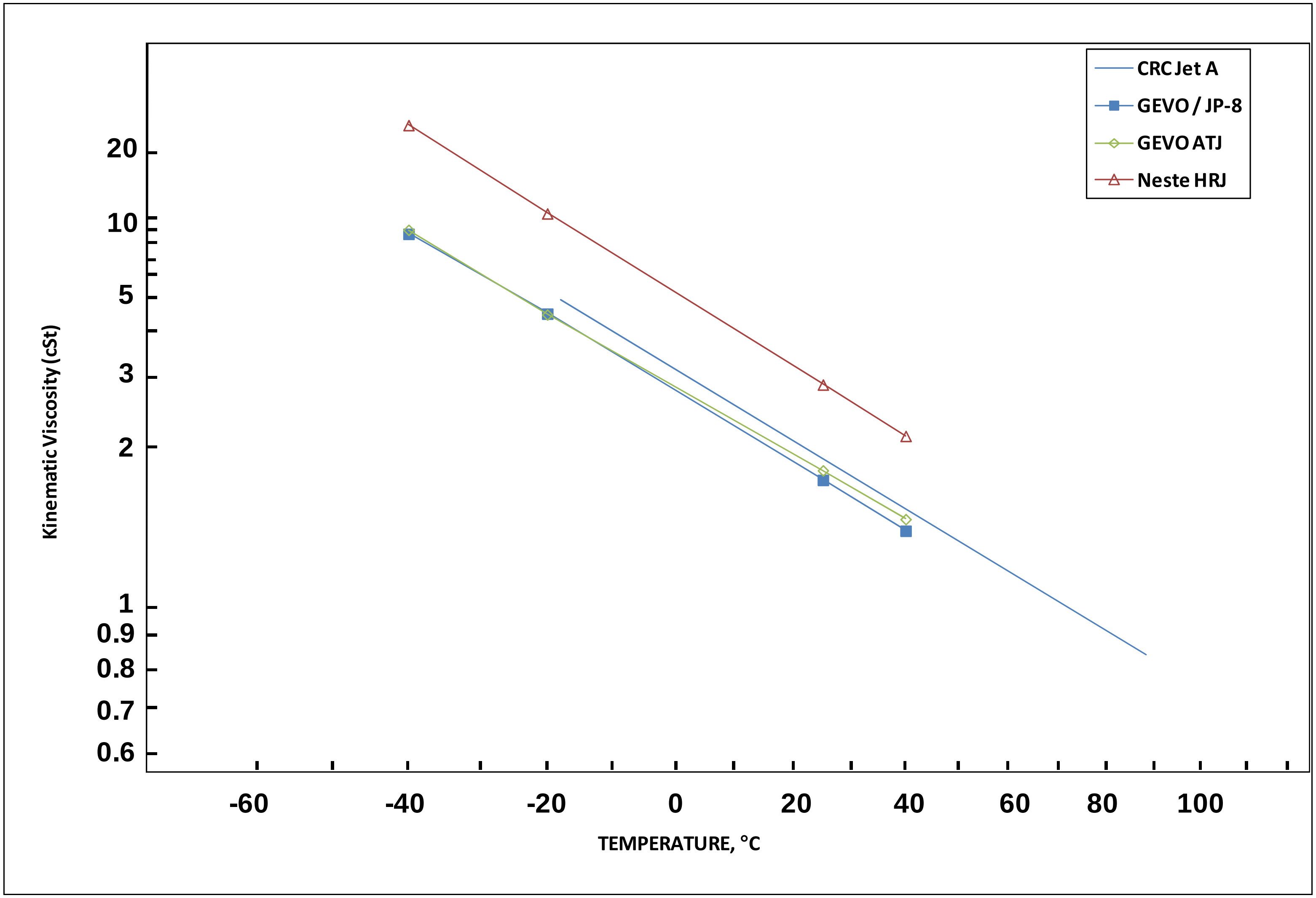

Figure E-15. Kinematic Viscosity (D445)

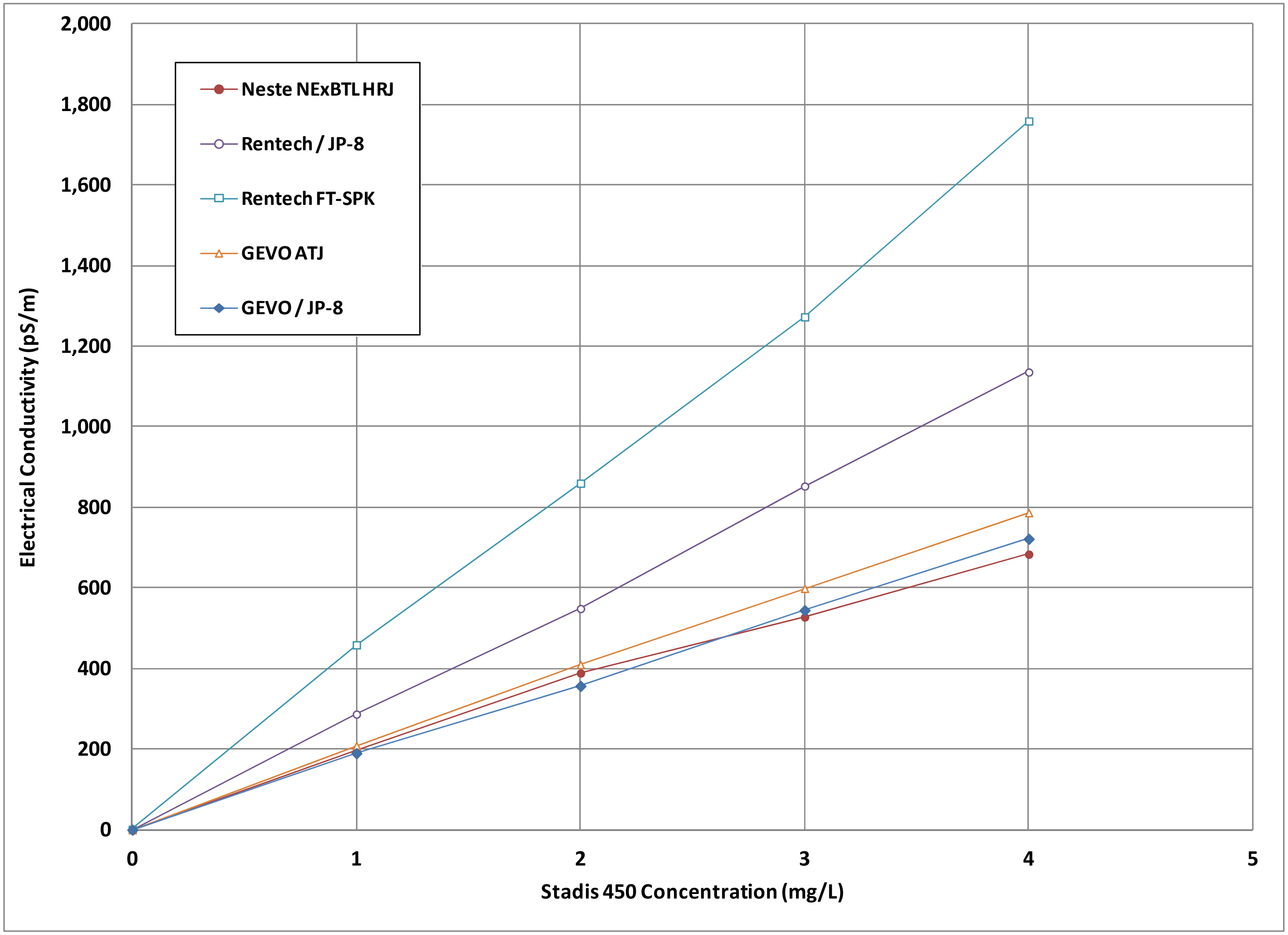

Figure E-16. Electrical Conductivity (D2624) vs. SDA Concentration

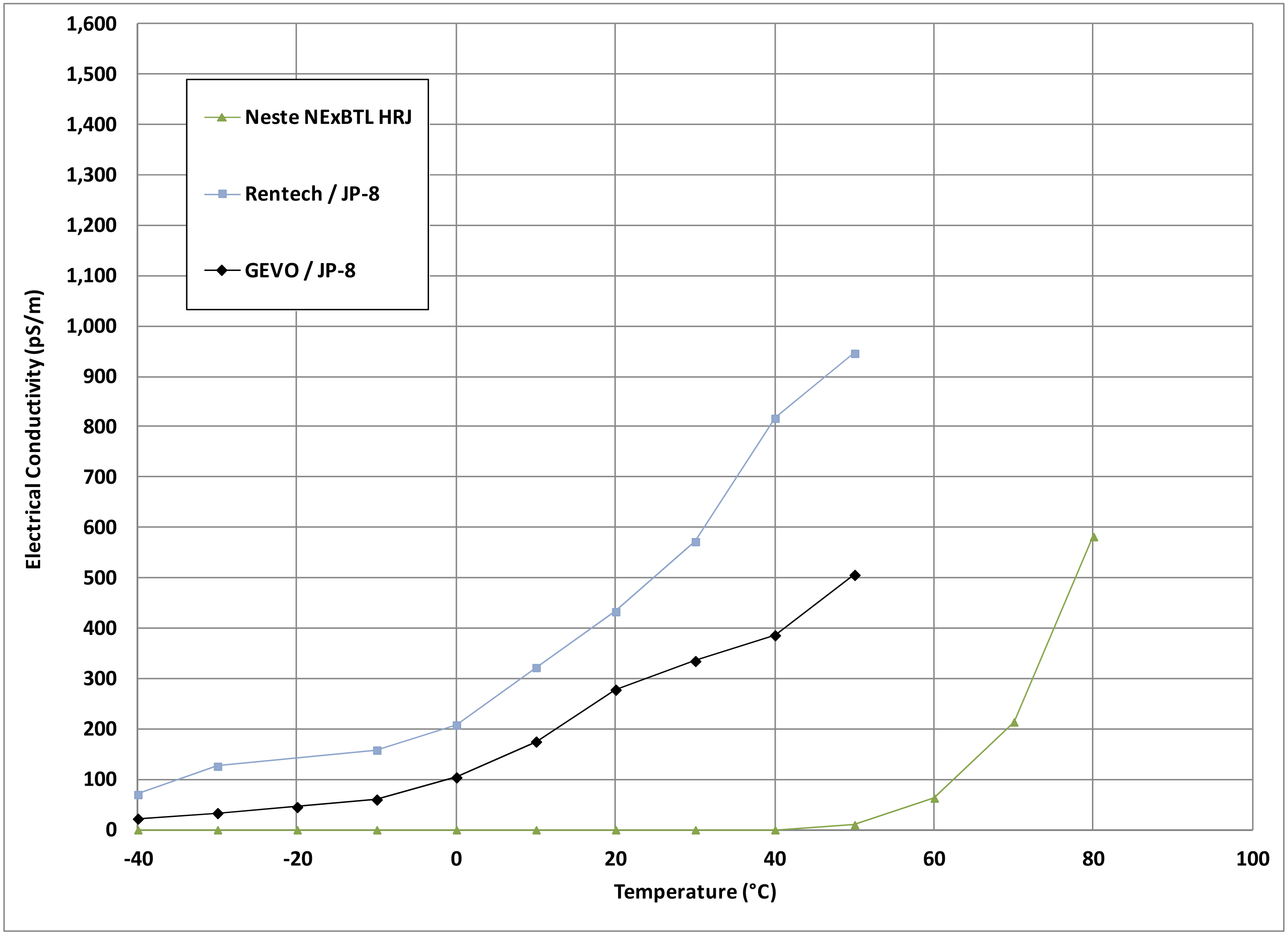

Figure E-17. Electrical Conductivity (D2624) vs. Temperature

E4.4.16 Elastomer Compatibility (O-rings)

O-ring evaluations performed on selected fuels are included in their respective appendices as plots of tensile strength and volume change. A summary of these results are shown in Figure E-18 and Figure E-19 for tensile strength and volume change, respectively. For tensile strength, the data is compared to a baseline run consisting of an unsoaked o-ring. The results are generally as we've come to expect. Neat fuels that contain no appreciable aromatics show a lack of swell, and in some cases shrinkage, of the elastomers. This is most evident in the R8 and GEVO ATJ. Even the 50/50 blends show only moderate swell (20-50%) relative to the Jet A / JP-8 samples. The tensile strength doesn't appear to be impacted substantially relative to fuel type. With respect to volume swell, the fluorosilicone shows moderate impact with all fuels while the viton shows only minor effects. The nitrile is the most fuel sensitive.

E5.0 CONCLUSIONS

The testing performed herein and supported by previous efforts, continues to provide strong evidence that blends composed of 50% synthetic fuel (FT SPK, HRJ SPK, and ATJ) and 50% petroleum-derived fuel should be more than adequate as drop-in replacements for current petroleum-derived fuels. However, the unique characteristics of these fuels exposed by this effort demonstrates the need for continued fit-for-purpose testing of emerging alternative aviation fuels.

By all accounts, the Rentech FT-SPK appeared to perform well similar to other FT-SPK fuels in the past. This work included two unique fuels not seen to date. The GEVO ATJ was the first alcohol-to-jet fuel studied under this program. With this fuel, we only saw minor issues with the distillation slopes due to the oligomerization process. The Neste NExBTL HRJ was different in many regards. Relative to other fuels studied under this program, this HRJ showed unusual distillation properties, little response to additive treatment, and failure to meet a number of basic specification properties. This fuel clearly stands out among all those tested to date.

Special studies were carried out to target specific issues like bulk modulus and water solubility. Isentropic bulk modulus was shown to provide more realistic data that affectively distinguishes fuel types. The next step will be to create a library of baseline data as a function of temperature and pressure. The water solubility study confirmed that some fuels have a slight predilection for water retention. Clay-treatment showed a minor improvement in some cases but had little effect on the subsequent blends made from the same. An SAE J1488 water separation test on the Rentech fuel demonstrated exceptional water removal characteristics. We continue to see some minor additive separation for those blends involving FSII and especially at low temperature. This may be an issue of needing to test at 4X the recommended treat rate per D4054. Tests conducted at 2X the recommended treat rate may be more appropriate for approved additives. Further work may be needed to investigate this issue.

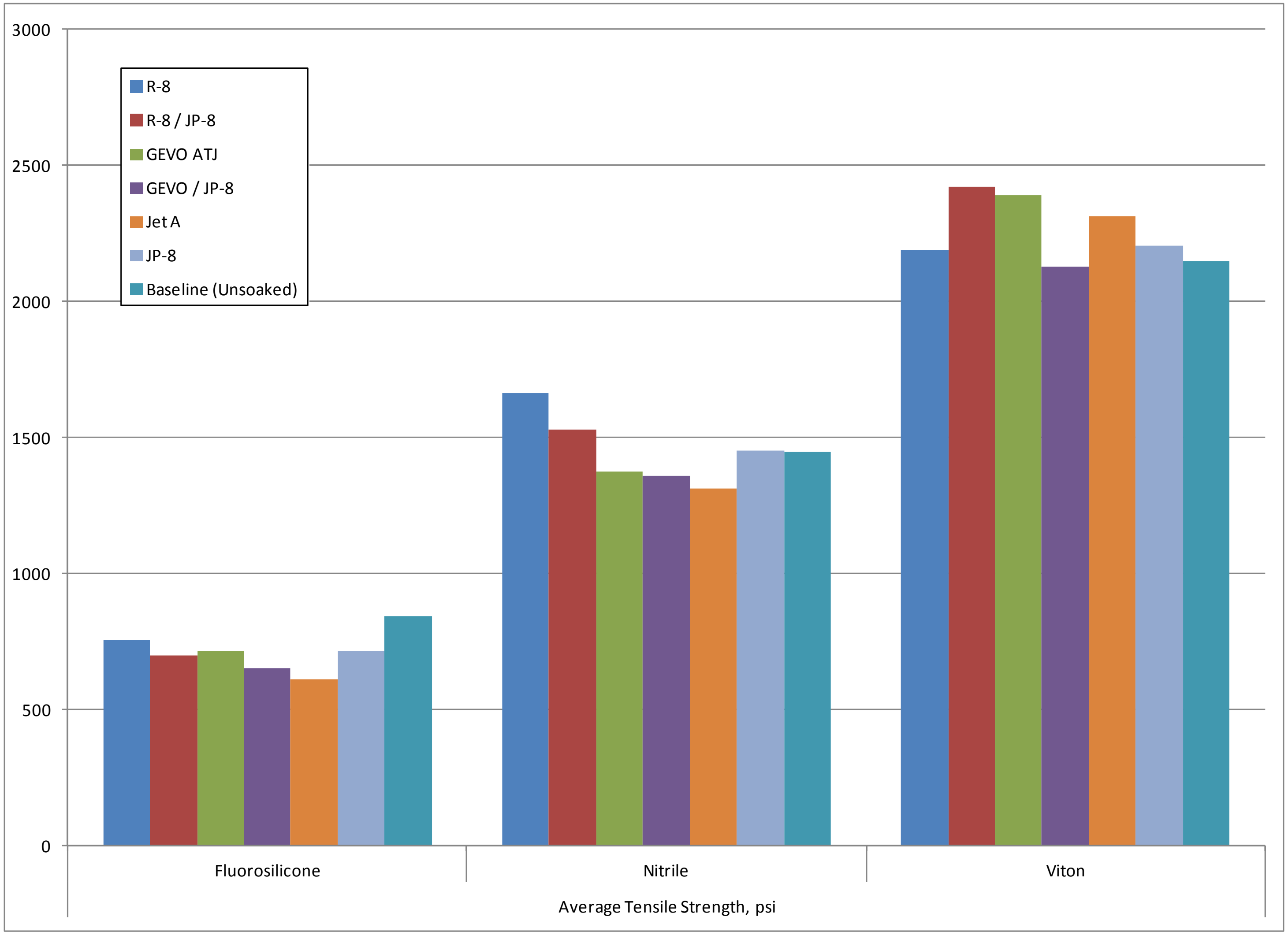

Figure E-18. Elastomer Compatibility – Tensile Strength

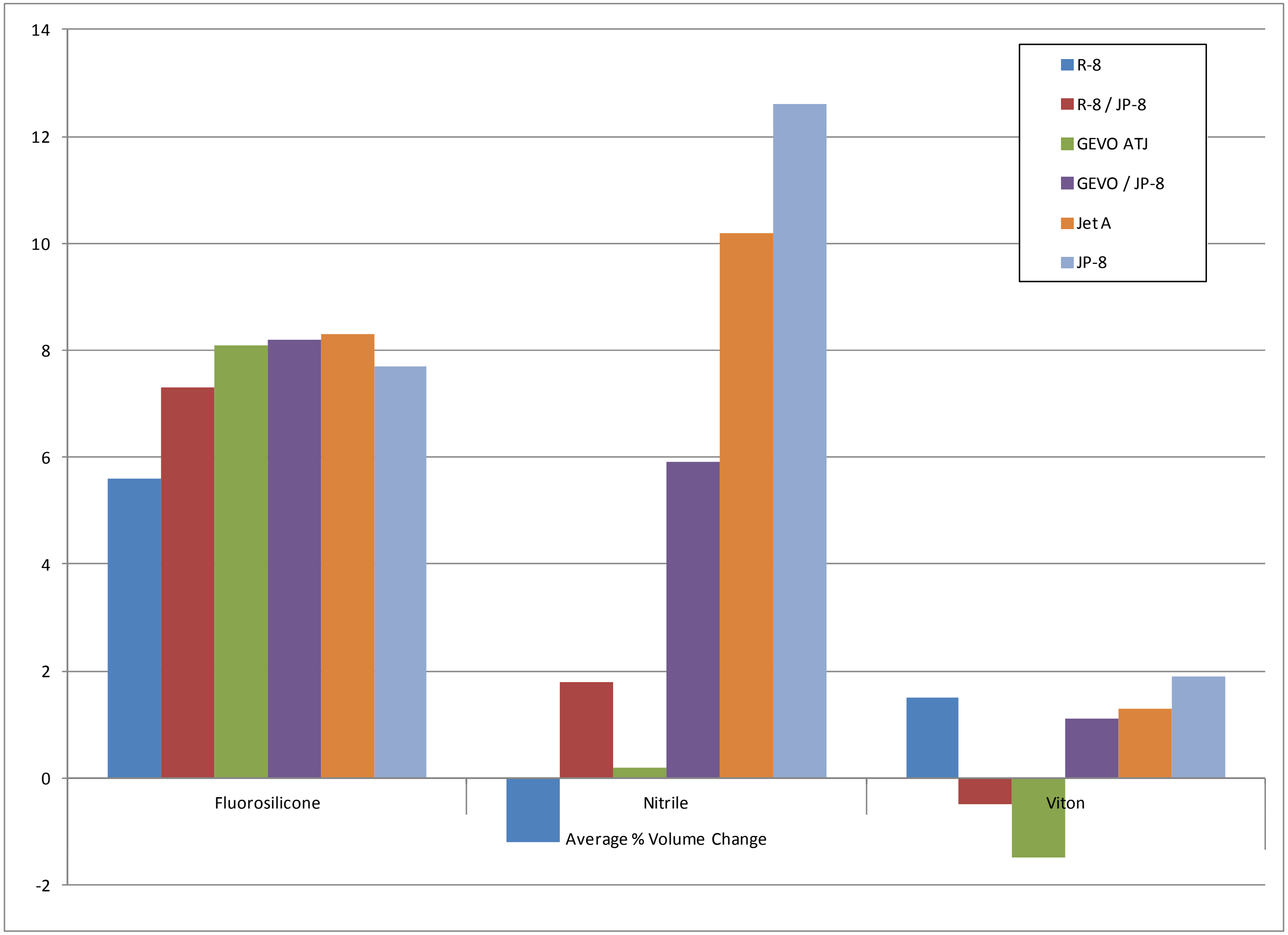

Figure E-19. Elastomer Compatibility – Volume Change

E6.0 RECOMMENDATIONS

E6.1 D4054 Revision

The need to expand aviation fuel testing to include fit-for-purpose tests has identified several shortcomings in the methods currently suggested. The problems include undocumented procedures, non-standard practices, impractical procedures, and limited availability of labs to perform the procedures. As of this writing, an effort is underway to revise D4054 to correct some of these problems.

E6.2 Bulk Modulus

Measuring isentropic bulk modulus through speed-of-sound appears to provide a more practical and accurate solution. SwRI's effort to construct such an apparatus capable of temperatures to 100°C and pressures to 30,000 psi is close to completion. Once complete, a study will be performed on a wide range of aviation fuels to form a baseline for future comparison.

E6.3 Feedstock Differences

At some point in the future, it may be of practical importance to obtain a better understanding of why certain fuels behave the way they do relative to certain properties (e.g. water retention, additive efficacy, etc). It seems clear that certain types of feedstocks, particularly those from waste oils, have some inherent characteristics that are not affected by the processing of the fuel.

E7.0 REFERENCES

1. Propulsion and Power Rapid Response Research and Development (R&D) Support - Delivery Order 0011: Analysis Of Synthetic Aviation Fuels, AFRL-RZ-WP-TR-2011-2084, April 2011.
2. Handbook of Aviation Fuel Properties, CRC Report No. 635, 3rd Edition, Coordinating Research Council, Alpharetta, GA, 2004.
3. CRC World Fuel Sampling Program, CRC Report No. 647, Coordinating Research Council, Alpharetta, GA, 2006.

E8.0 ACRONYMS

Acronym	Description
°C	Celsius
°F	Fahrenheit
µm	micrometer
AA	atomic absorption
BOCLE	ball-on-cylinder lubricity evaluator
BTU	British Thermal Unit
CI/LI	Corrosion Inhibitor/Lubricity Improver
CLEEN	Continuous Lower Energy, Emissions, and Noise
cSt	centistokes
DCN	derived cetane number
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FFP	fit-for-purpose
FT	Fischer-Tropsch
FTM	Federal Test Method
g	gram
GTL	gas to liquid
HEFA	Hydroprocessed Esters and Fatty Acids
HFRR	high frequency reciprocating rig
HRJ	hydroprocessed renewable jet
HRJ8	50/50 blend of HRJ/Jet A containing JP-8 additives
Hz	hertz
ID	ignition delay
IPK	iso-paraffinic kerosene
IQT™	Ignition Quality Tester
JFTOT	Jet Fuel Thermal Oxidation Tester
K	Kelvin
kg	kilogram
kHz	kilohertz
kJ	kilojoule
kPa	kilopascal
L	liter
lb	pound
LEL	lower explosion limit
lpm	liters per minute
m	meter
mg	milligram
MJ	megajoule
mJ	millijoule
mL	milliliter
mm	millimeter
mN	millinewton
MPa	megapascal
ms	millisecond
NMR	nuclear magnetic resonance
ppb	part per billion

E8.0 ACRONYMS *(Cont'd)*

Acronym	Description
ppm	part per million
psi(a or g)	pounds per square inch (absolute or gauge)
SAE	Society of Automotive Engineers
SDA	static dissipator additive
SPK	synthetic paraffinic kerosene
TWA WRE	time-weighted average water removal efficiency
UEL	upper explosion limit
W	watts

Appendix E-1

R8 HRJ Data

Table E-3. R8 and R8/JP-8 Evaluations

Test	Method	Units	CL10-2127	CL10-2128
			R8 w/additives (POSF7385)	R8/JP-8 (POSF7386)
Bulk Physical and Performance Properties				
Lubricity (BOCLE) – neat fuel	D5001	mm	0.72	0.57
Lubricity (BOCLE) vs. CI/LI Concentration (clay-treated fuel)	D5001			
0 mg/L		mm	0.92	0.81
5 mg/L		mm	0.84	0.74
10 mg/L		mm	0.66	0.61
15 mg/L		mm	0.57	0.58
20 mg/L		mm	0.54	0.52
Lubricity (SLBOCLE) – neat fuel	D6078	mm	2250	2500
Lubricity (SLBOCLE) vs. CI/LI Concentration (clay-treated fuel)	D6078			
0 mg/L		g	1450	1650
5 mg/L		g	1450	1500
10 mg/L		g	1250	1700
15 mg/L		g	2000	1750
20 mg/L		g	1500	1950
Lubricity (HFRR) – neat fuel	D6079	mm	0.64	0.73
Lubricity (HFRR) vs. CI/LI Concentration (clay-treated fuel)	D6079			
0 mg/L		mm	0.70	0.71
5 mg/L		mm	0.68	0.65
10 mg/L		mm	0.71	0.65
15 mg/L		mm	0.71	0.64
20 mg/L		mm	0.68	0.65
Density	D4052			
15°C		g/cm^3	0.7612	0.7831
25°C		g/cm^3	0.7540	0.7758
40°C		g/cm^3	0.7430	0.7647
Surface tension	D1331A			
-9.0°C		mN/m	25.7	--
25°C		mN/m	24.4	--
40.6°C		mN/m	22.7	--

Table E-3. R8 and R8/JP-8 Evaluations

Test	Method	Units	CL10-2127	CL10-2128
			R8 w/additives (POSF7385)	R8/JP-8 (POSF7386)
-8.8°C		mN/m	--	27.2
25°C		mN/m	--	25.0
42.2°C		mN/m	--	23.5
Speed of Sound (30°C)		m/s	1247	1267
Isentropic Bulk Modulus (30°C)		psig	169283	179717
Electrical Properties				
Upper Explosion Limit (UEL), @100°C	E681	%	4.4 ± 0.1	4.2 ± 0.1
Lower Explosion Limit (LEL), @100°C	E681	%	0.4 ± 0.1	0.4 ± 0.1
Compatibility				
Elastomer Compatibility (O-Ring Tests)	SwRI		*See Figure E-20, Figure 21, Figure E-22*	*See Figure 23, Figure E-24, Figure E-25*
Miscellaneous				
Minimum Ignition Energy @ 100°C	E582	mJ	0.76	0.63

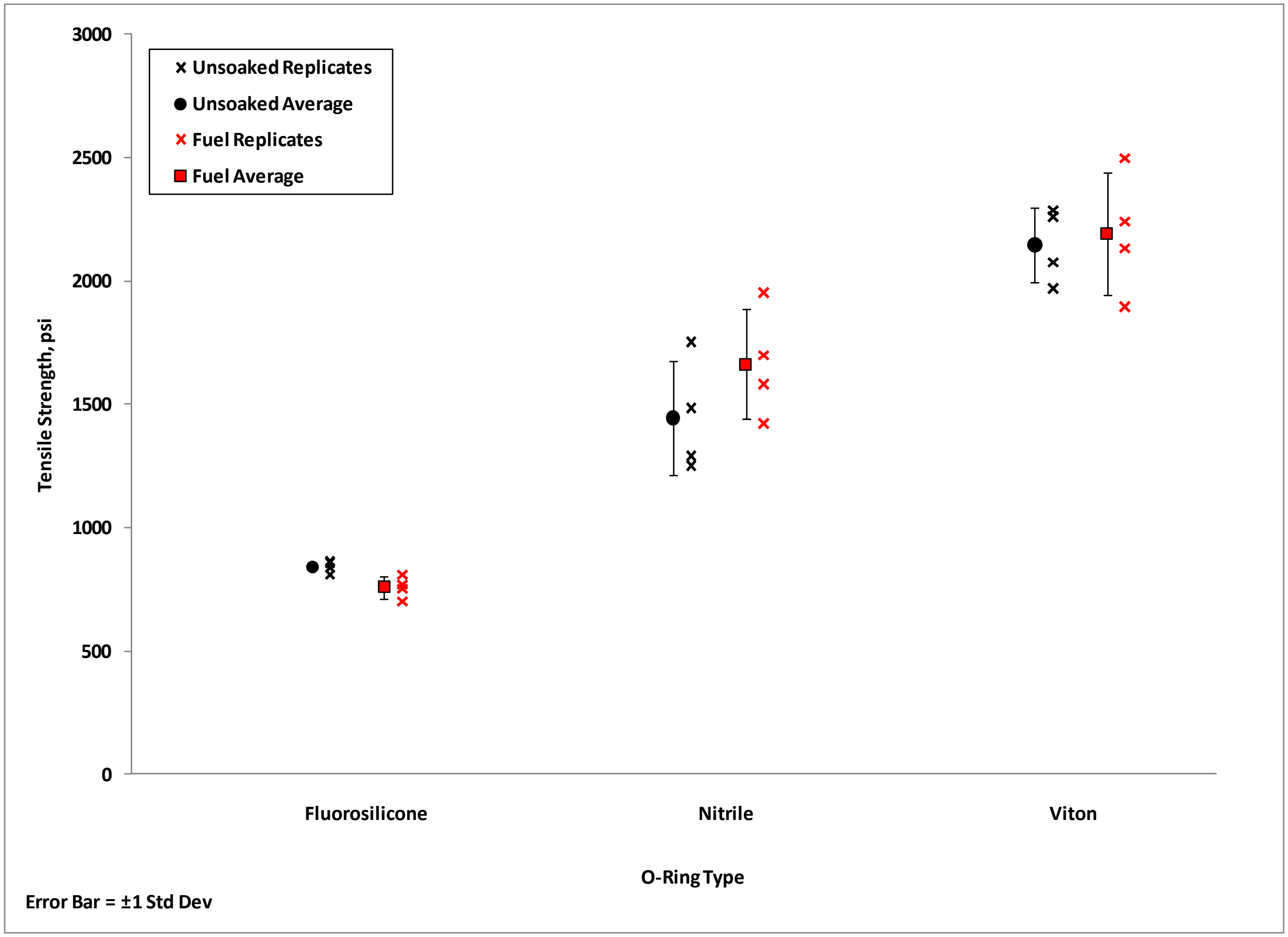

Figure E-20. R8 (CL11-2127) O-Ring Data – Tensile Strength

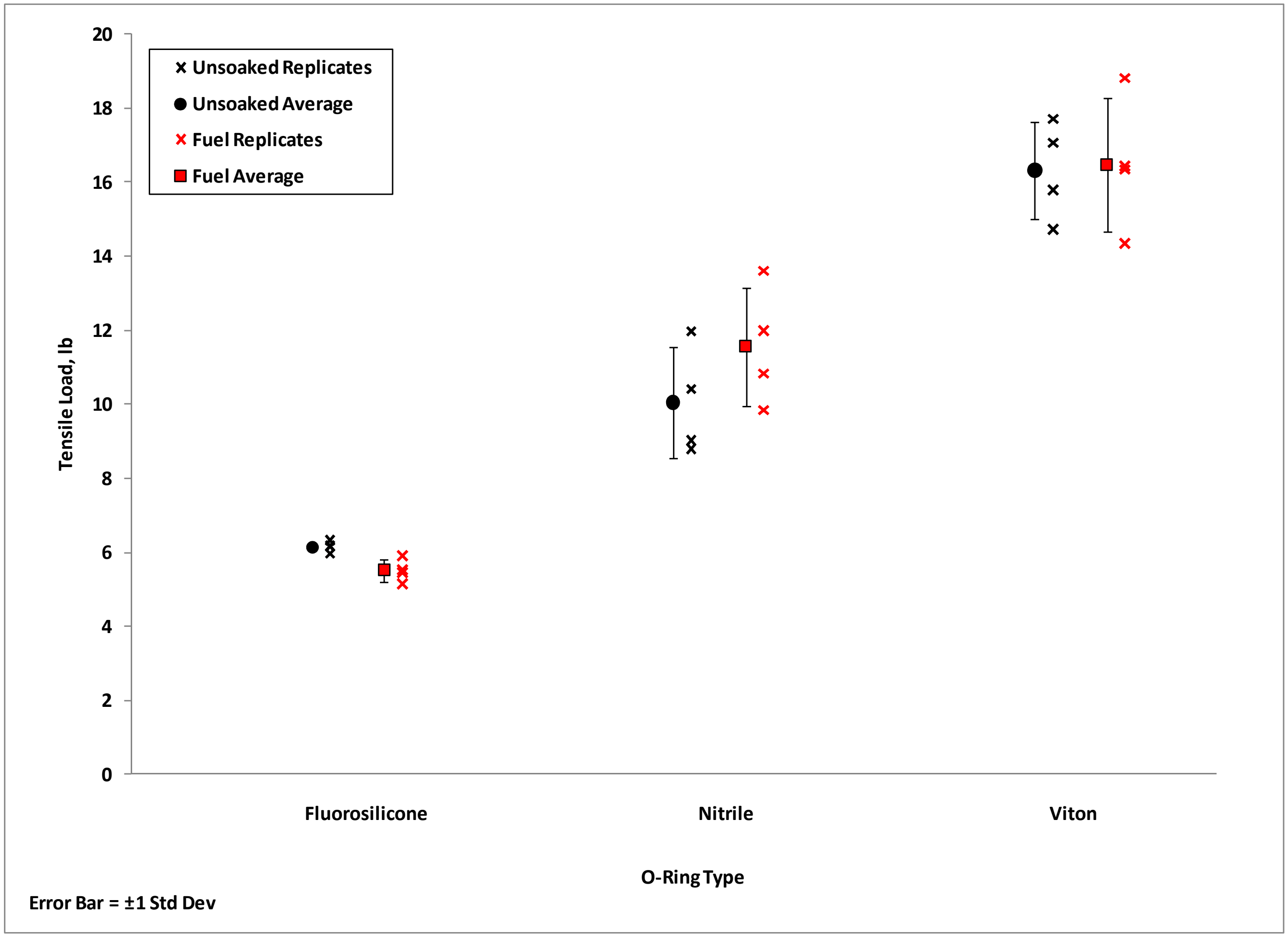

Figure E-21. R8 (CL11-2127) O-Ring Data – Tensile Load

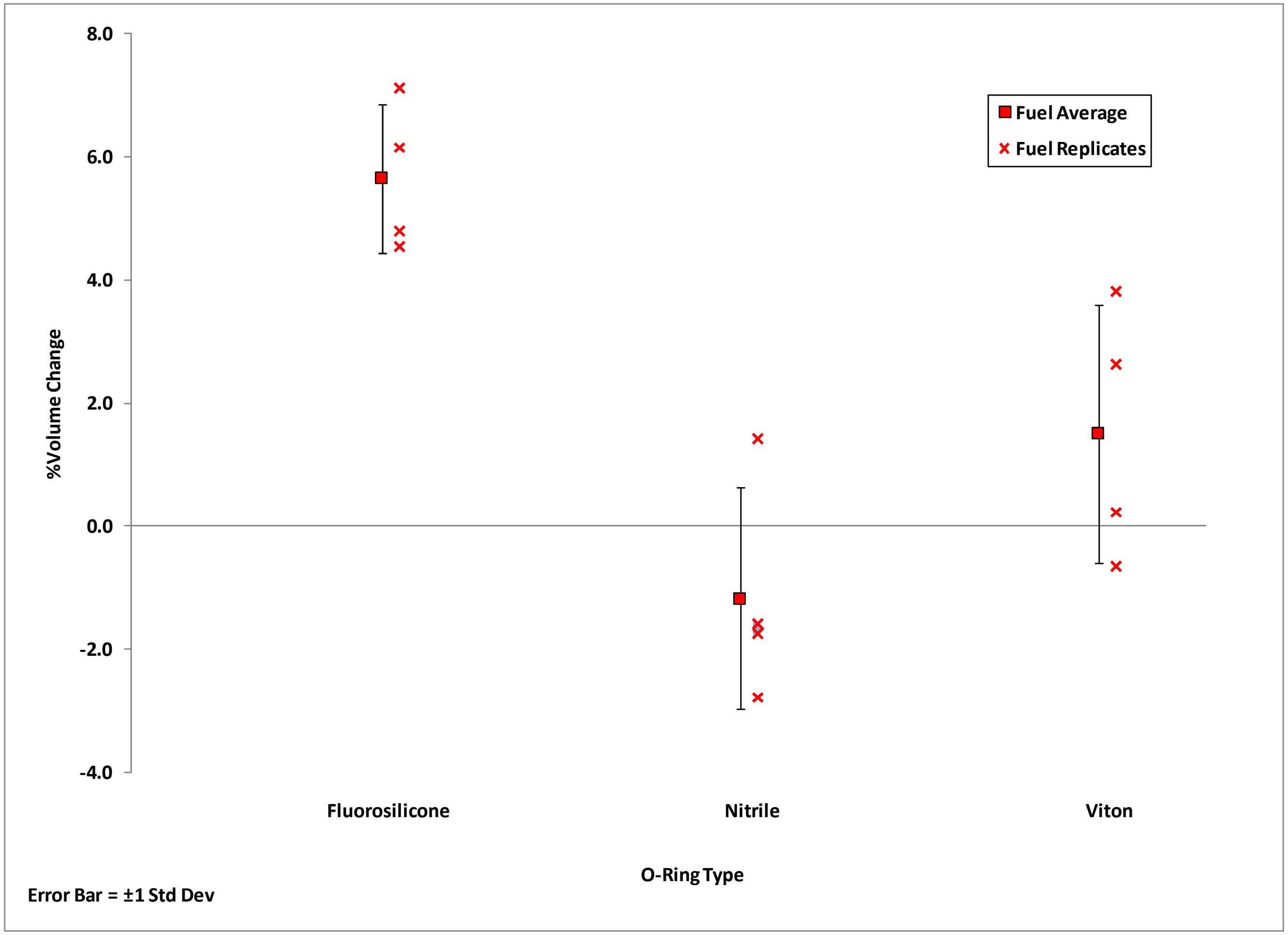

Figure E-22. R8 (CL11-2127) O-Ring Data – Volume Change

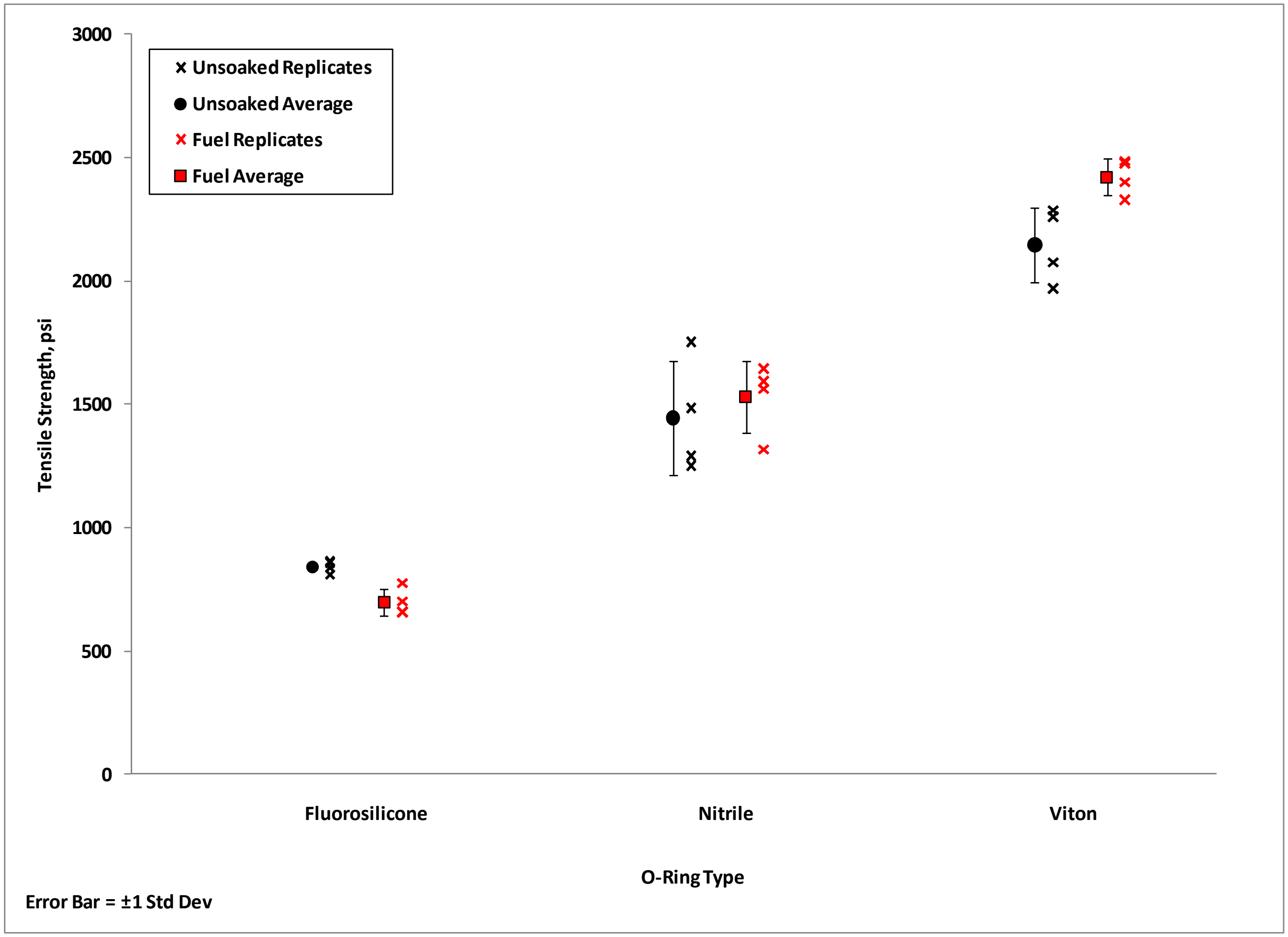

Figure E-23. R8 / JP-8 (CL11-2128) O-Ring Data – Tensile Strength

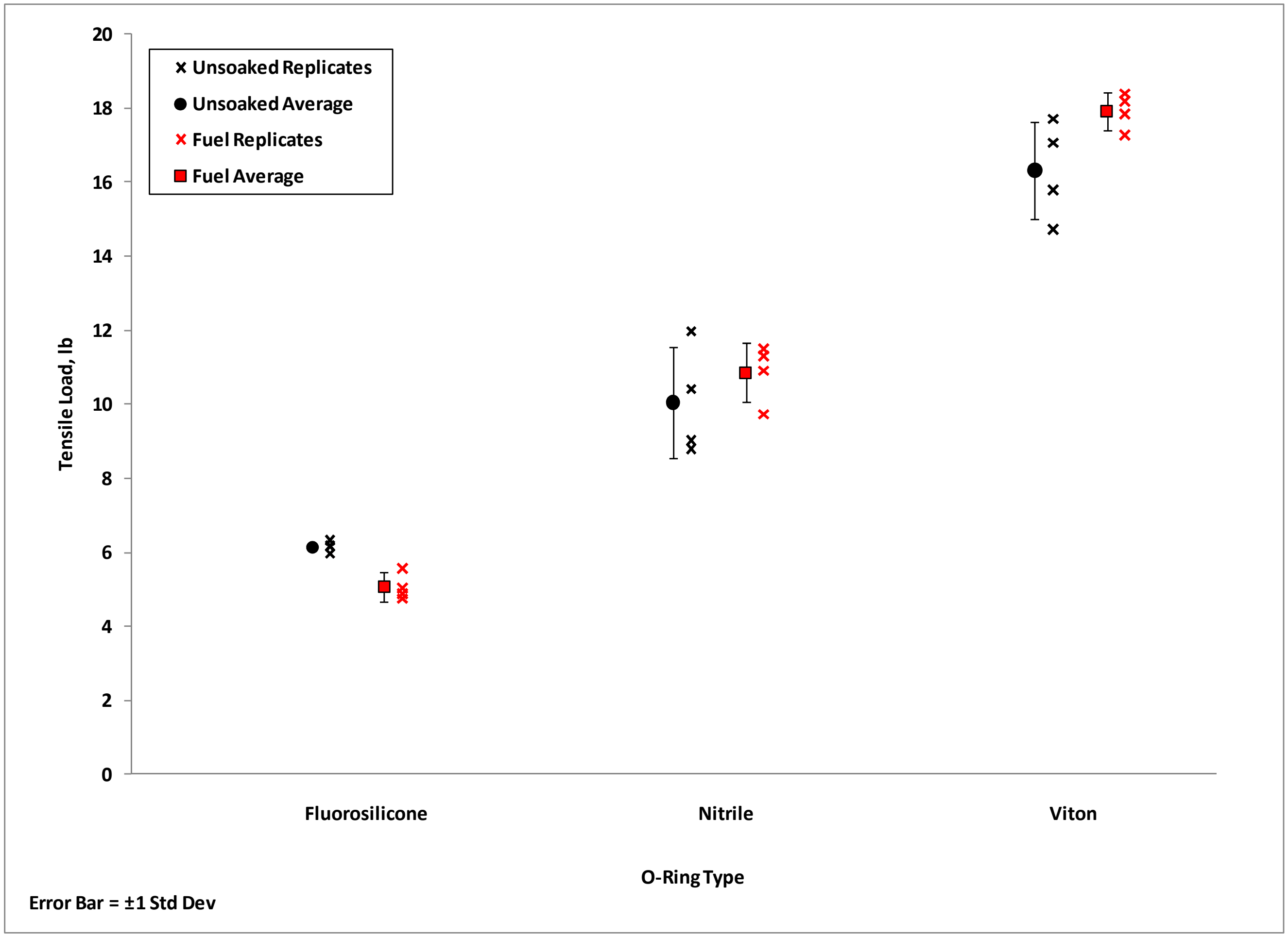

Figure E-24. R8 / JP-8 (CL11-2128) O-Ring Data – Tensile Load

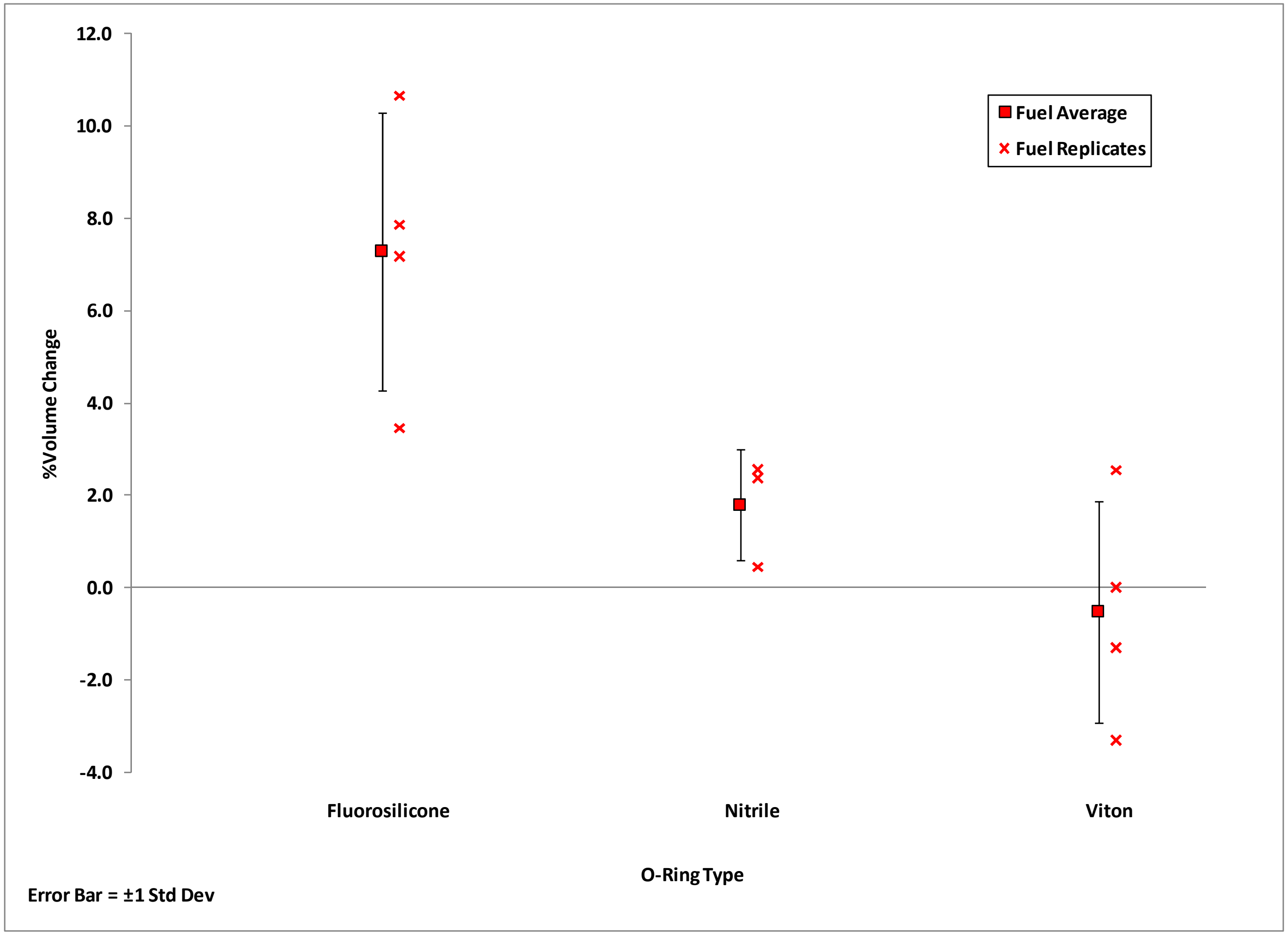

Figure E-25. R8 / JP-8 (CL11-2128) O-Ring Data – Volume Change

Appendix E-2

GEVO ATJ Data

Table E-4. GEVO and GEVO/JP-8 Fit-For-Purpose Testing

Test	Method	Units	CL11-2513 GEVO / JP-8 Blend (POSF7505)	CL11-2512 GEVO (POSF7504)
Chemistry				
Hydrocarbon Types by Mass Spec	D2425			
Paraffins		mass%	64.0	90.4
Monocycloparaffins		mass%	24.7	9.4
Dicycloparaffins		mass%	0.0	0.0
Tricycloparaffins		mass%	0.0	0.0
TOTAL SATURATES		mass%	88.7	99.8
Alkylbenzenes		mass%	6.7	0.1
Indans/Tetralins		mass%	3.3	0.0
Indenes		mass%	0.2	0.0
Naphthalene		mass%	0.3	0.0
Naphthalene, Alkyl		mass%	0.6	0.0
Acenaphthenes		mass%	0.1	0.0
Acenaphthylenes		mass%	0.1	0.0
Tricyclic Aromatics		mass%	0.0	0.0
TOTAL AROMATICS		mass%	11.3	0.1
Aromatic Content	D1319			
Aromatics		vol%	9.0	0.7
Olefins		vol%	1.6	0.6
Saturates		vol%	89.4	98.7
Carbon/Hydrogen	D5291			
Carbon		%	85.34	84.60
Hydrogen		%	14.57	15.36
Hydrogen Content (NMR)	D3701	mass%	14.61	15.45
Carbonyls, Alcohols, Esters, Phenols				
Alcohols	EPA 8015B	mg/kg	*See Report Below*	*See Report Below*
Carbonyls, Esters	EPA 8260B	mg/kg		
Phenols	EPA 8270C	mg/kg		
Nitrogen Content	D4629	mg/kg	1.0	3.0
Copper by AA	D3237M	ppb	15	25
Elemental Analysis	D7111			
Al		ppb	177.0	<100
Ba		ppb	<100	<100
Ca		ppb	138.0	<100
Cr		ppb	<100	<100
Cu		ppb	<100	<100
Fe		ppb	<100	<100

Table E-4. GEVO and GEVO/JP-8 Fit-For-Purpose Testing

Test	Method	Units	CL11-2513 GEVO / JP-8 Blend (POSF7505)	CL11-2512 GEVO (POSF7504)
Li		ppb	<100	<100
Pb		ppb	<100	<100
Mg		ppb	<100	<100
Mn		ppb	<100	<100
Mo		ppb	<100	<100
Ni		ppb	<100	<100
K			<1ppm	<1ppm
Na			<1ppm	<1ppm
Si			<4.3ppm	7.2ppm
Ag		ppb	<100	<100
Ti		ppb	<100	<100
V		ppb	<100	<100
Zn		ppb	<100	<100
Bulk Physical and Performance Properties				
Distillation	D86			
IBP		°C	166.2	169.9
5%		°C	175.2	175.3
10%		°C	177.6	176.4
15%		°C	179.7	177.2
20%		°C	181.2	177.4
30%		°C	183.8	178.3
40%		°C	187.6	179.0
50%		°C	190.5	179.9
60%		°C	196.5	180.7
70%		°C	203.6	182.5
80%		°C	217.0	185.5
90%		°C	236.3	197.8
95%		°C	248.4	220.7
FBP		°C	260.4	236.2
Residue		%	1.2	1.4
Loss		%	0.9	0.6
T50-T10		°C	12.9	3.5
T90-T10		°C	58.7	21.4
Simulated Distillation	D2887			
IBP		°C	111.5	*N/A*
5%		°C	159.6	*N/A*
10%		°C	170.4	*N/A*
15%		°C	171.5	*N/A*
20%		°C	172.1	*N/A*
25%		°C	172.6	*N/A*
30%		°C	172.9	*N/A*

Table E-4. GEVO and GEVO/JP-8 Fit-For-Purpose Testing

Test	Method	Units	CL11-2513 GEVO / JP-8 Blend (POSF7505)	CL11-2512 GEVO (POSF7504)
35%		°C	173.3	*N/A*
40%		°C	173.8	*N/A*
45%		°C	176.3	*N/A*
50%		°C	182.1	*N/A*
55%		°C	186.7	*N/A*
60%		°C	195.2	*N/A*
65%		°C	201.8	*N/A*
70%		°C	212.1	*N/A*
75%		°C	220.4	*N/A*
80%		°C	230.2	*N/A*
85%		°C	238.8	*N/A*
90%		°C	247.6	*N/A*
95%		°C	261.9	*N/A*
FBP		°C	297.7	*N/A*
Vapor pressure (Absolute)	D6378			
0 °C		psi	0.15	0.18
10 °C		psi	0.24	0.22
20 °C		psi	0.29	0.27
30 °C		psi	0.34	0.32
40 °C		psi	0.41	0.39
50 °C		psi	0.50	0.48
60 °C		psi	0.63	0.62
70 °C		psi	0.82	0.83
80 °C		psi	1.07	1.11
90 °C		psi	1.39	1.51
100 °C		psi	1.84	2.04
110 °C		psi	2.42	2.74
120 °C		psi	3.20	3.74
JFTOT Breakpoint	D3241BP	°C		
Test Temperature		°C	300.0	--
ASTM Code		rating	2.0	--
Maximum Pressure Drop		mm Hg	0.0	--
JFTOT @ 325°C	D3241BP	°C		
Test Temperature		°C	--	325.0
ASTM Code		rating	--	1.0
Maximum Pressure Drop		mm Hg	--	0.0
Lubricity (BOCLE)	D5001	mm	0.63	0.73
Lubricity (BOCLE) vs. CI/LI Concentration	D5001			
0 mg/L		mm	0.91	1.09
5 mg/L		mm	0.83	0.98
10 mg/L		mm	0.77	0.90

Table E-4. GEVO and GEVO/JP-8 Fit-For-Purpose Testing

Test	Method	Units	CL11-2513 GEVO / JP-8 Blend (POSF7505)	CL11-2512 GEVO (POSF7504)
15 mg/L		mm	0.71	0.83
20 mg/L		mm	0.64	0.78
Lubricity (HFRR)	D6079	µm	730	*N/A*
Lubricity (HFRR) vs. CI/LI Concentration	D6079			
0 mg/L		µm	740	*N/A*
5 mg/L		µm	730	*N/A*
10 mg/L		µm	700	*N/A*
15 mg/L		µm	700	*N/A*
20 mg/L		µm	690	*N/A*
Lubricity (Scuffing Load BOCLE)	D6078	g	2500	*N/A*
Lubricity (Scuffing Load BOCLE) vs. CI/LI Concentration	D6078			
0 mg/L		g	1350	*N/A*
5 mg/L		g	1600	*N/A*
10 mg/L		g	2000	*N/A*
15 mg/L		g	2150	*N/A*
20 mg/L		g	2550	*N/A*
Kinematic Viscosity	D445			
-40		cSt	8.68	9.01
-20		cSt	4.53	4.50
25°C		cSt	1.71	1.79
40°C		cSt	1.36	1.43
Specific Heat Capacity	E2716			
-25°C		kJ/kg.K	1.704	*N/A*
0°C		kJ/kg.K	1.772	*N/A*
25°C		kJ/kg.K	1.853	*N/A*
50°C		kJ/kg.K	1.952	*N/A*
100°C		kJ/kg.K	2.159	*N/A*
150°C		kJ/kg.K	2.373	*N/A*
Density	D4052			
5°C		g/cm^3	0.7886	0.7640
15°C		g/cm^3	0.7816	0.7556
40°C		g/cm^3	0.7626	0.7385
60°C		g/cm^3	0.7477	0.7239
80°C		g/cm^3	0.7328	0.7091
Surface tension	D1331A			
-11°C		mN/m	26.1	*N/A*
22°C		mN/m	23.9	*N/A*
39.0°C		mN/m	22.6	*N/A*
Speed of Sound @ 30°C		m/s	1231.0	1181.0
Isentropic Bulk Modulus @ 30°C		psig	169372.0	150769.0
Thermal Conductivity	SwRI			

Table E-4. GEVO and GEVO/JP-8 Fit-For-Purpose Testing

Test	Method	Units	CL11-2513 GEVO / JP-8 Blend (POSF7505)	CL11-2512 GEVO (POSF7504)
0°C		W/m.K	0.0994	*N/A*
25°C		W/m.K	0.0989	*N/A*
50°C		W/m.K	0.0984	*N/A*
Water Content	D6304	ppm	66	52
Water Content	D6304			
-10°C		ppm	51	--
40°C		ppm	152	--
50°C		ppm	223	--
Water Content	D6304			
-10°C		ppm	--	32
40°C		ppm	--	146
51°C		ppm	--	158
Flash Point - Tag Closed	D56	°C	44.0	47.0
Freeze Point (manual)	D2386	°C	-56.0	*N/A*
Freeze Point	D5972	°C	-56.90	<-81
Electrical Properties				
Dielectric Constant (10kHz)	SwRI			
-36.2°C		---	2.153	--
-22°C		---	2.131	--
0°C		---	2.103	--
30°C		---	2.064	--
50°C		---	2.041	--
80°C		---	*N/A*	--
-41.2°C		---	--	2.095
-20.0°C		---	--	2.067
0.2°C		---	--	2.042
30°C		---	--	2.009
50°C		---	--	1.986
80°C		---	--	*N/A*
Electrical Conductivity	D2624	pS/m	205.0	1.0
Electrical Conductivity vs. SDA Concentration	D2624			
0 mg/L		pS/m	0.0	0.0
1 mg/L		pS/m	190.0	209.0
2 mg/L		pS/m	357.0	410.0
3 mg/L		pS/m	545.0	599.0
4 mg/L		pS/m	722.0	787.0
Electrical Conductivity vs. Temperature	D2624			
-40		pS/m	22.0	*N/A*
-30		pS/m	33.0	*N/A*
-20		pS/m	45.0	*N/A*
-10		pS/m	60.0	*N/A*

Table E-4. GEVO and GEVO/JP-8 Fit-For-Purpose Testing

Test	Method	Units	CL11-2513 GEVO / JP-8 Blend (POSF7505)	CL11-2512 GEVO (POSF7504)
0		pS/m	104.0	*N/A*
10		pS/m	175.0	*N/A*
20		pS/m	278.0	*N/A*
30		pS/m	335.0	*N/A*
40		pS/m	386.0	*N/A*
50		pS/m	506.0	*N/A*
Ground Handling Properties and Safety				
MSEP	D3948	rating	59.0	*N/A*
Storage Stability - Peroxides @65°C	D3703			
0 week		mg/kg	0.200	*N/A*
1 week		mg/kg	1.000	*N/A*
2 week		mg/kg	1.064	*N/A*
3 week		mg/kg	1.800	*N/A*
6 week		mg/kg	2.000	*N/A*
Storage Stability – Potential Gums	D5304			
16 hours		mg/100mL	0.2	0.2
Upper Explosion Limit (UEL), @100°C	E681	%	6.1 ± 0.1	*N/A*
Lower Explosion Limit (LEL), @100°C	E681	%	0.3 ± 0.1	*N/A*
Autoignition temperature	E659			
Hot Flame Autoignition Temperature		°C	*not observed*	*N/A*
Hot Flame Lag Time		seconds	*not observed*	*N/A*
Cool Flame Autoignition Temperature		°C	248.0	*N/A*
Cool Flame Lag Time		seconds	39.7	*N/A*
Barometric Pressure		mm Hg	733.0	*N/A*
Reaction Threshold Temperature		°C	220.0	*N/A*
Hot surface ignition	FTM 791-6053	°F	1200.0	*N/A*
Compatibility				
Fuel/Additive Compatibility (4x treat rate)	D4054B			
FSII		effect	droplets observed in jar	no separation
SDA		effect	no separation	no separation
CI/LI		effect	no separation	no separation
MDA		effect	no separation	no separation
AO-30		effect	no separation	no separation
+100		effect	no separation	no separation
Additive Cocktail (MDA, AO, SDA, CI/LI, FSII,+100)		effect	separation - thin yellow layer	separation - thin yellow layer
Elastomer Compatibility (O-Ring Tests)	SwRI		*See Figure E-26, Figure E-27, Figure E-28*	*See Figure E-29, Figure E-30, Figure E-31*
Miscellaneous				
Copper Strip Corrosion (100°C for 2 hours)	D130	rating	1A	1A
Smoke Point	D1322	mm	25.2	*N/A*
Naphthalene Content	D1840	vol%	0.0	*N/A*

Table E-4. GEVO and GEVO/JP-8 Fit-For-Purpose Testing

Test	Method	Units	CL11-2513 GEVO / JP-8 Blend (POSF7505)	CL11-2512 GEVO (POSF7504)
Sulfur - Mercaptan	D3227	mass%	<0.0003	<0.0003
Acid Number	D3242	mg KOH/g	0.006	0.005
Existent Gums	D381	mg/100mL	<0.5	<0.5
Heat of Combustion	D4809			
BTUHeat_Gross		BTU/lb	20064.4	*N/A*
BTUHeat_Net		BTU/lb	18735.2	*N/A*
MJHeat_Gross		MJ/kg	46.7	*N/A*
MJHeat_Net		MJ/kg	43.6	*N/A*
Sulfur Content - (Antek)	D5453	ppm	187.50	0.50
Ignition Quality Test (IQT)	D6890			
Ignition Delay, ID		ms	6.0	21.9
Derived Cetane Number, DCN			35.4	15.1
Minimum Ignition Energy @ 100°C	E582	mJ	0.28	*N/A*
Sulfur Content - (XRY)	D2622	ppm	<10	*N/A*

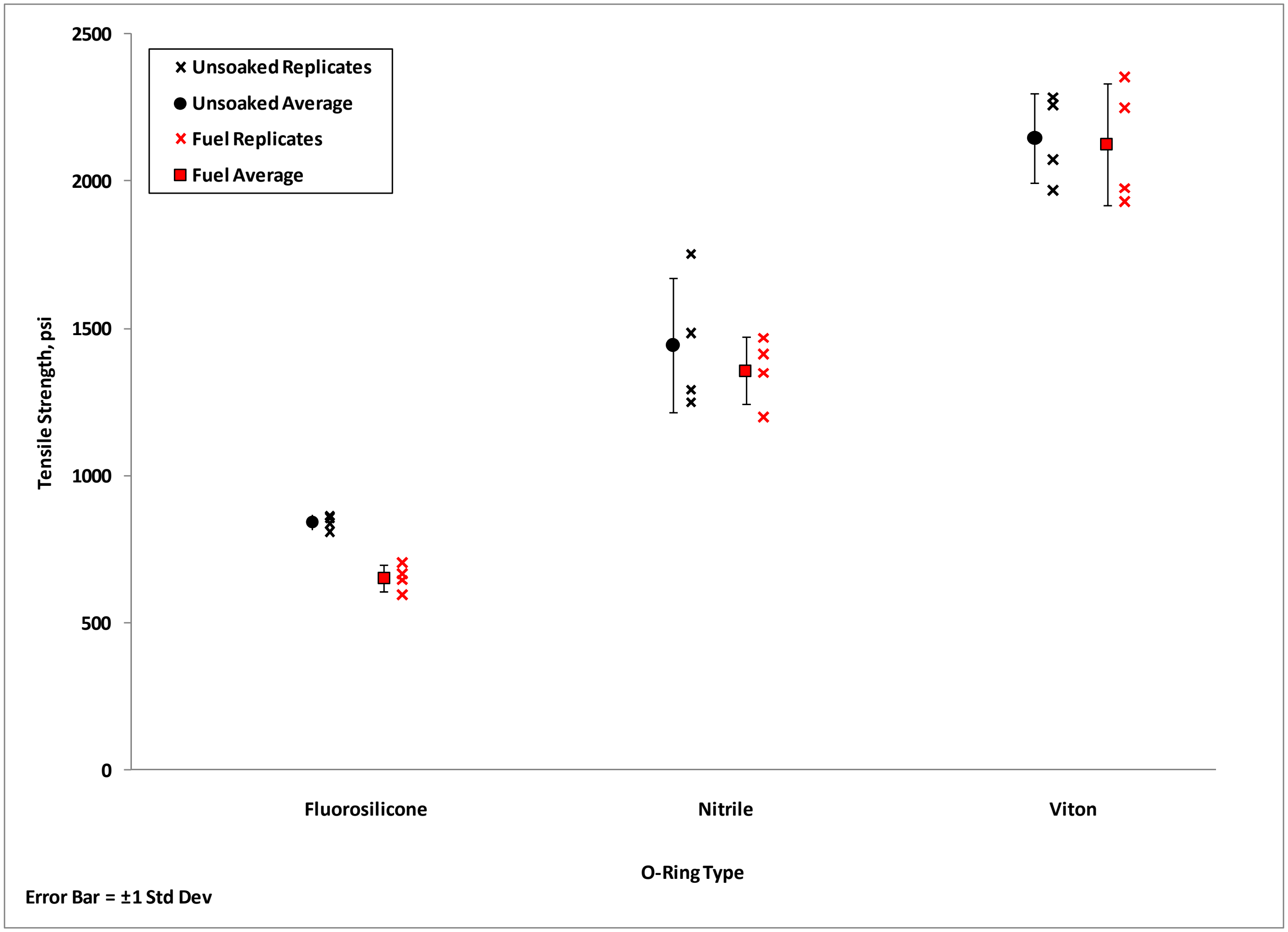

Figure E-26. GEVO ATJ / JP-8 (CL11-2513) O-Ring Data – Tensile Strength

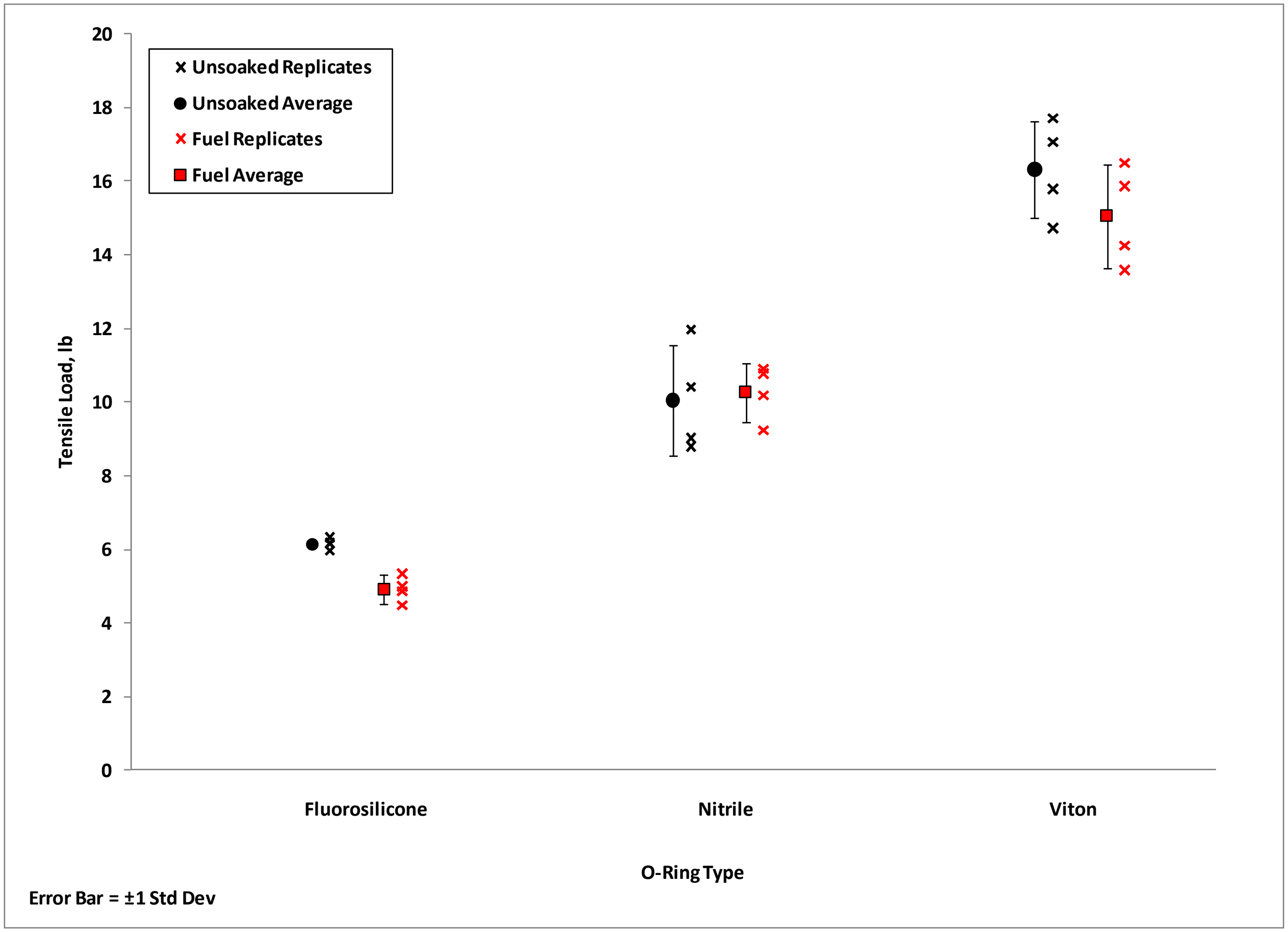

Figure E-27. GEVO ATJ / JP-8 (CL11-2513) O-Ring Data – Tensile Load

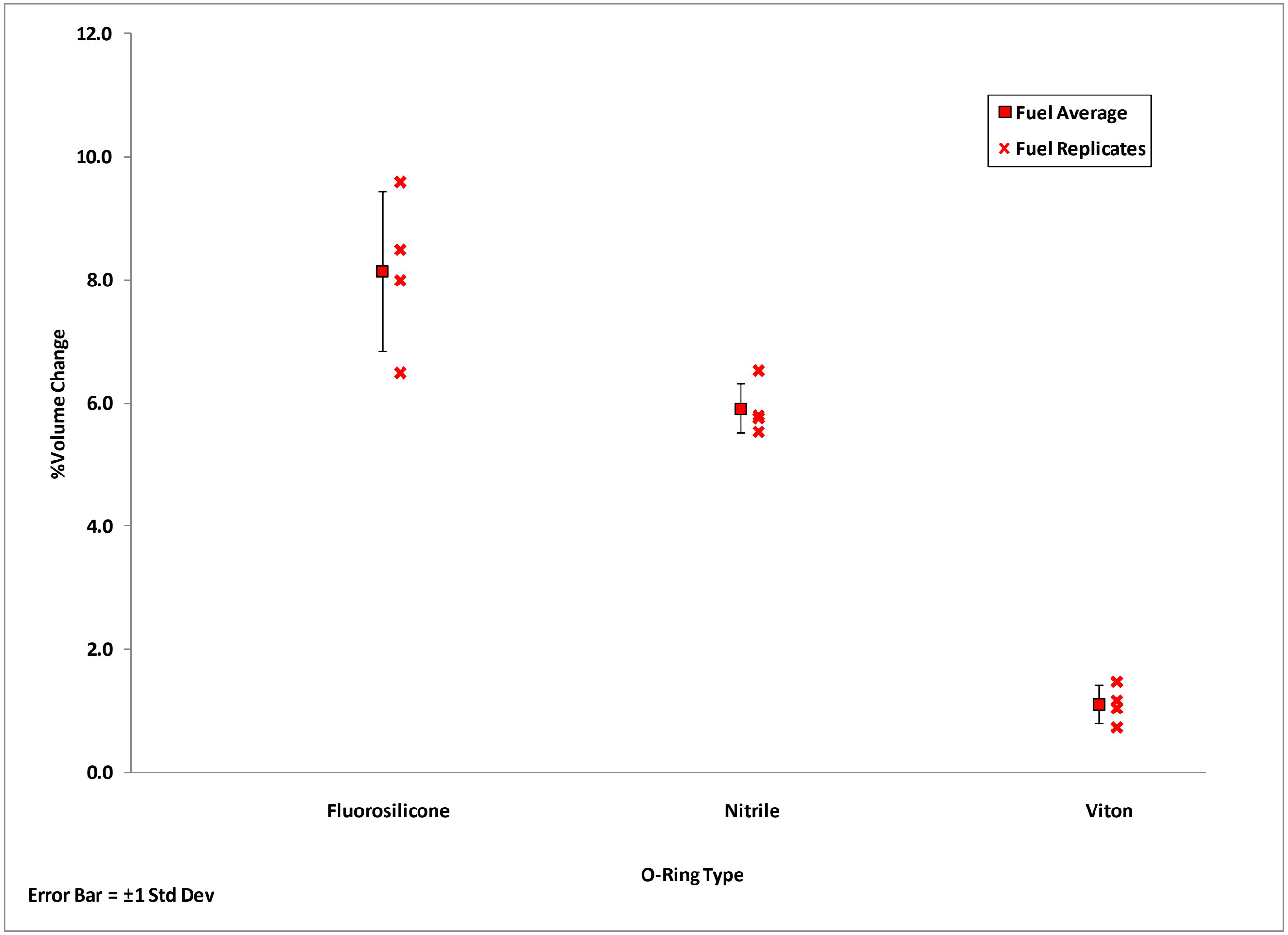

Figure E-28. GEVO ATJ / JP-8 (CL11-2513) O-Ring Data – Volume Change

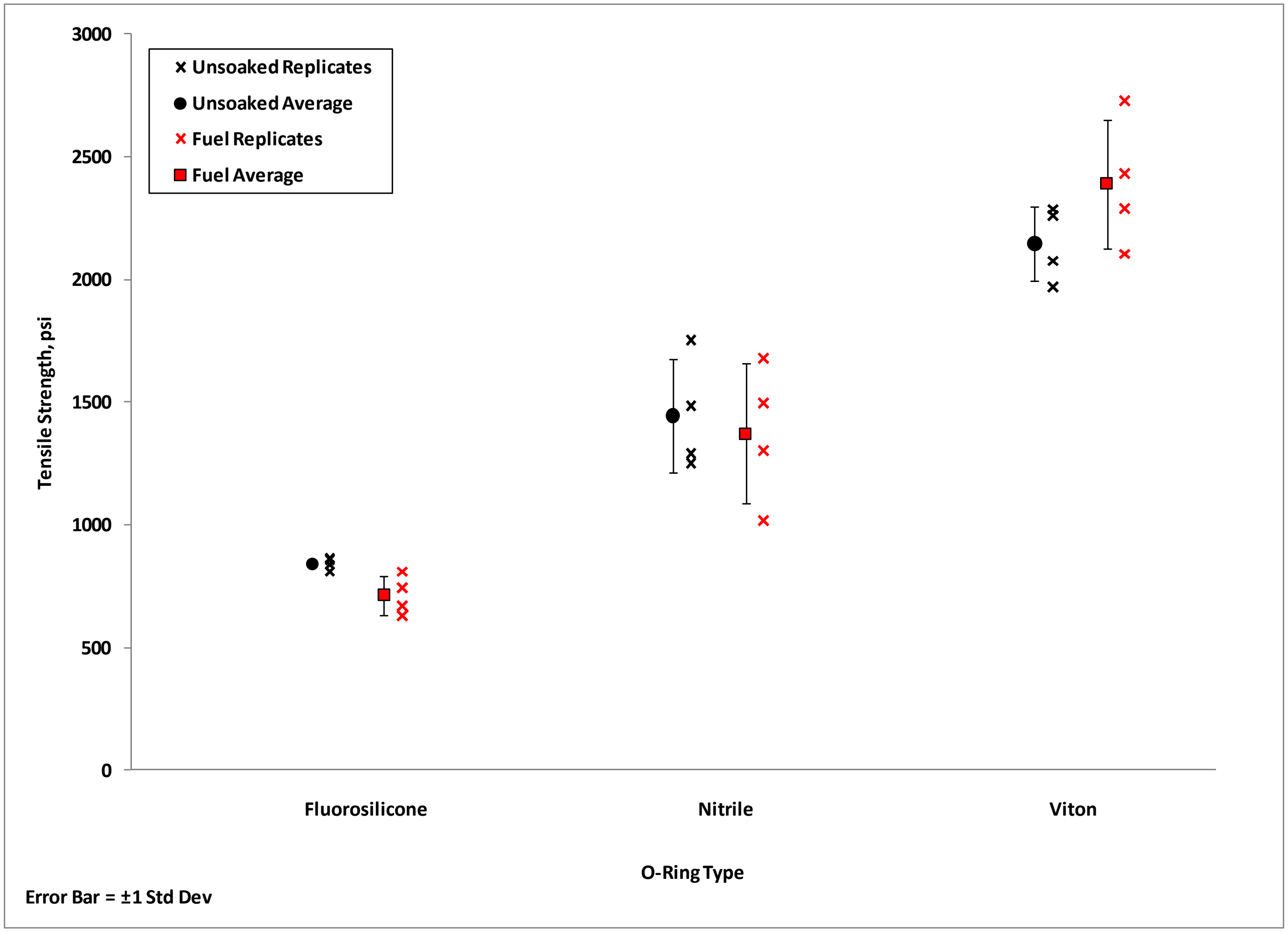

Figure E-29. GEVO ATJ (CL11-2512) O-Ring Data – Tensile Strength

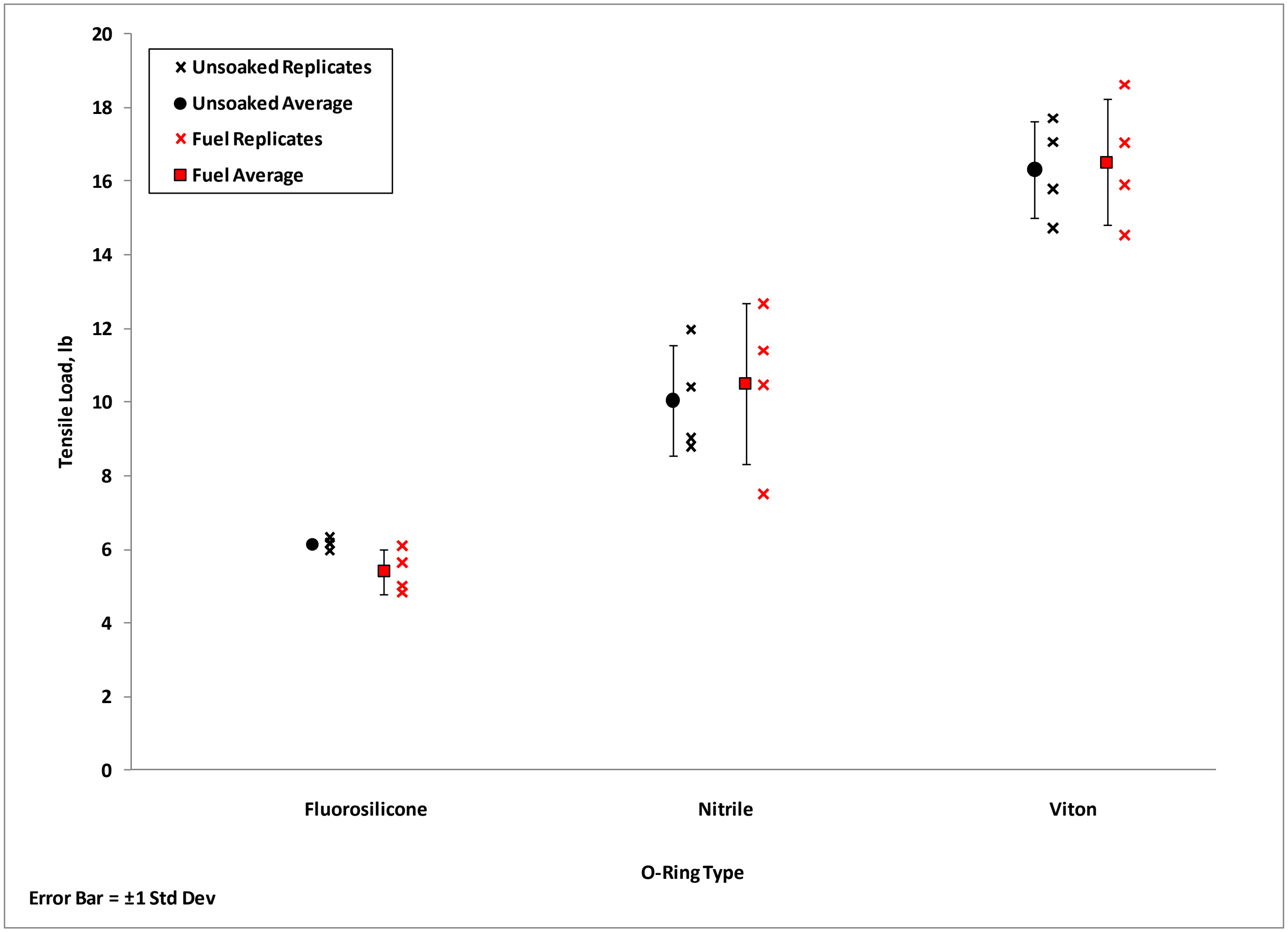

Figure E-30. GEVO ATJ (CL11-2512) O-Ring Data – Tensile Load

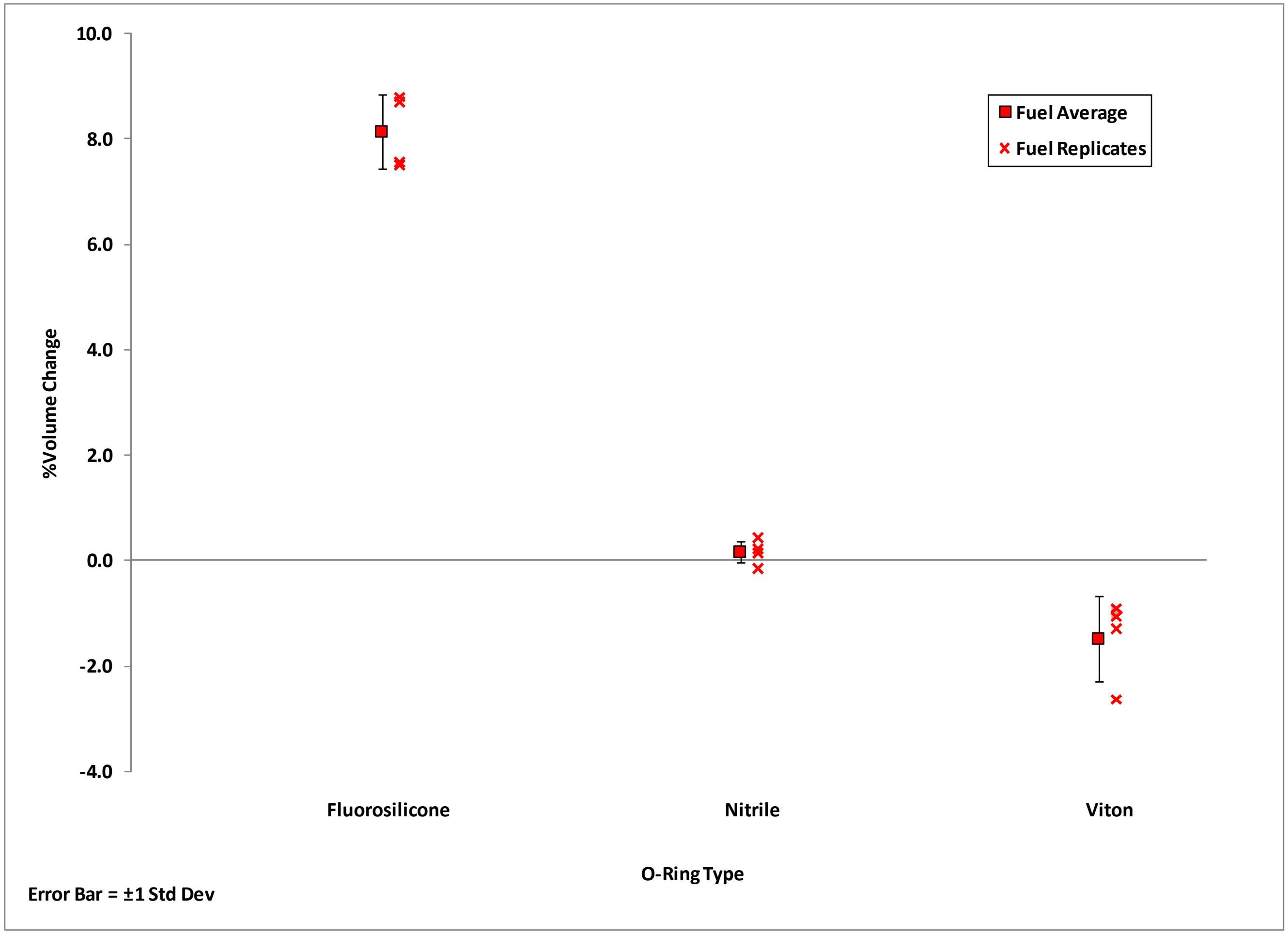

Figure E-31. GEVO ATJ (CL11-2512) O-Ring Data – Volume Change

Analytical Report 428081

for

Southwest Research Institute

Project Manager: Scott Hutzler

16246.02.001

20-OCT-11

Collected By: Client

XENCO Laboratories
Trans West Analytical Services, LLC

Celebrating 20 Years of commitment to excellence in Environmental Testing Services

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XENCO Laboratories
Trans West Analytical Services, LLC

20-OCT-11

Project Manager: **Scott Hutzler**
Southwest Research Institute
6220 Culebra Road
P.O. Box 28510
San Antonio, TX 78228

Reference: XENCO Report No: **428081**
16246.02.001
Project Address:

Scott Hutzler :

We are reporting to you the results of the analyses performed on the samples received under the project name referenced above and identified with the XENCO Report Number 428081. All results being reported under this Report Number apply to the samples analyzed and properly identified with a Laboratory ID number. Subcontracted analyses are identified in this report with either the NELAC certification number of the subcontract lab in the analyst ID field, or the complete subcontracted report attached to this report.

Unless otherwise noted in a Case Narrative, all data reported in this Analytical Report are in compliance with NELAC standards. Estimation of data uncertainty for this report is found in the quality control section of this report unless otherwise noted. Should insufficient sample be provided to the laboratory to meet the method and NELAC Matrix Duplicate and Matrix Spike requirements, then the data will be analyzed, evaluated and reported using all other available quality control measures.

The validity and integrity of this report will remain intact as long as it is accompanied by this letter and reproduced in full, unless written approval is granted by XENCO Laboratories. This report will be filed for at least 5 years in our archives after which time it will be destroyed without further notice, unless otherwise arranged with you. The samples received, and described as recorded in Report No. 428081 will be filed for 60 days, and after that time they will be properly disposed without further notice, unless otherwise arranged with you. We reserve the right to return to you any unused samples, extracts or solutions related to them if we consider so necessary (e.g., samples identified as hazardous waste, sample sizes exceeding analytical standard practices, controlled substances under regulated protocols, etc).

We thank you for selecting XENCO Laboratories to serve your analytical needs. If you have any questions concerning this report, please feel free to contact us at any time.

Respectfully,

Skip Harden
Project Manager

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CASE NARRATIVE

Client Name: Southwest Research Institute
Project Name: 16246.02.001

Project ID:		*Report Date:*	*20-OCT-11*
Work Order Number:	*428081*	*Date Received:*	*09/22/2011*

Sample receipt non conformances and comments:
Methods 8015D, 8260B and 8270C were analyzed by Xenco-Houston.

Sample receipt non conformances and comments per sample:

None

Flagging Criteria

Arizona Flags

All method blanks, laboratory spikes, and/or matrix spikes met quality control objectives for the parameters associated with this Work Order except as detailed below or on the Data Qualifier page of this report. Data Qualifiers used in this report are in accordance with ADEQ Arizona Data Qualifiers, Revision 3.0 9/20/2007. Data qualifiers (flags) contained within this analytical report have been issued to explain a quality control deficiency, and do not affect the quality (validity) of the data unless noted otherwise in the case narrative.

D1 Sample required dilution due to matrix.

D2 Sample required dilution due to high concentration of target analyte.

L1 The associated blank spike recovery was above laboratory acceptance limits.

L2 The associated blank spike recovery was below laboratory acceptance limits.

M2 Matrix spike recovery was low; the associated blank spike recovery was acceptable.

S8 The analysis of the sample required a dilution such that the surrogate recovery calculation does not provide any useful information. The associated blank spike recovery was acceptable.

T4 Tentatively identified compound. Concentration is estimated and based on the closest internal standard.

Sample Cross Reference 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Sample Id	Matrix	Date Collected	Sample Depth	Lab Sample Id
CL11-2512	S	09-21-11 00:00		428081-001
CL11-2513	S	09-21-11 00:00		428081-002

XENCO Laboratories
Trans West Analytical Services, LLC

Certificate of Analytical Results 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Sample Id: CL11-2512	**Matrix:** Solid	**Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-001	**Date Collected:** Sep-21-11 00:00	

Analytical Method: Volatiles by SW 8260B		**Prep Method:** SW5030B
Tech: CYE		**% Moisture:**
Analyst: CYE	**Date Prep:** Oct-05-11 12:46	**Basis:** Wet Weight
Seq Number: 871755		SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Benzene	71-43-2	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Bromobenzene	108-86-1	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Bromochloromethane	74-97-5	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Bromodichloromethane	75-27-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Bromoform	75-25-2	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Methyl bromide	74-83-9	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
MTBE	1634-04-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
tert-Butylbenzene	98-06-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Sec-Butylbenzene	135-98-8	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
n-Butylbenzene	104-51-8	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Carbon Tetrachloride	56-23-5	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Chlorobenzene	108-90-7	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Chloroethane	75-00-3	<50.0	50.0	mg/kg	10/05/11 13:33	D1	5000
Chloroform	67-66-3	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Methyl Chloride	74-87-3	<50.0	50.0	mg/kg	10/05/11 13:33	D1	5000
2-Chlorotoluene	95-49-8	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
4-Chlorotoluene	106-43-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
p-Cymene (p-Isopropyltoluene)	99-87-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,2-Dibromo-3-Chloropropane	96-12-8	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Dibromochloromethane	124-48-1	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,2-Dibromoethane	106-93-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Methylene bromide	74-95-3	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,2-Dichlorobenzene	95-50-1	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,3-Dichlorobenzene	541-73-1	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,4-Dichlorobenzene	106-46-7	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Dichlorodifluoromethane	75-71-8	<25.0	25.0	mg/kg	10/05/11 13:33	D1L2	5000
1,2-Dichloroethane	107-06-2	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,1-Dichloroethane	75-34-3	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
trans-1,2-dichloroethylene	156-60-5	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
cis-1,2-Dichloroethylene	156-59-2	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,1-Dichloroethene	75-35-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
2,2-Dichloropropane	594-20-7	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,3-Dichloropropane	142-28-9	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,2-Dichloropropane	78-87-5	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
trans-1,3-dichloropropene	10061-02-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,1-Dichloropropene	563-58-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
cis-1,3-Dichloropropene	10061-01-5	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Ethylbenzene	100-41-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Hexachlorobutadiene	87-68-3	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Isopropylbenzene	98-82-8	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000

Project: Phoenix XENCO - Master Project

Certificate of Analytical Results 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Sample Id: CL11-2512	**Matrix:** Solid	**Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-001	**Date Collected:** Sep-21-11 00:00	

Analytical Method: Volatiles by SW 8260B			**Prep Method:** SW5030B
Tech: CYE			**% Moisture:**
Analyst: CYE		**Date Prep:** Oct-05-11 12:46	**Basis:** Wet Weight
Seq Number: 871755			SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Naphthalene	91-20-3	<50.0	50.0	mg/kg	10/05/11 13:33	D1	5000
Methylene Chloride	75-09-2	<100	100	mg/kg	10/05/11 13:33	D1	5000
n-Propylbenzene	103-65-1	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Styrene	100-42-5	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,1,1,2-Tetrachloroethane	630-20-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,1,2,2-Tetrachloroethane	79-34-5	<25.0	25.0	mg/kg	10/05/11 13:33	D1L1	5000
Tetrachloroethylene	127-18-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Toluene	108-88-3	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,2,4-Trichlorobenzene	120-82-1	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,2,3-Trichlorobenzene	87-61-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,1,2-Trichloroethane	79-00-5	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,1,1-Trichloroethane	71-55-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Trichloroethylene	79-01-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Trichlorofluoromethane	75-69-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,2,3-Trichloropropane	96-18-4	<25.0	25.0	mg/kg	10/05/11 13:33	D1L1	5000
1,2,4-Trimethylbenzene	95-63-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
1,3,5-Trimethylbenzene	108-67-8	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
Vinyl Chloride	75-01-4	<10.0	10.0	mg/kg	10/05/11 13:33	D1	5000
o-Xylene	95-47-6	<25.0	25.0	mg/kg	10/05/11 13:33	D1	5000
m,p-Xylenes	1330-20-7	<50.0	50.0	mg/kg	10/05/11 13:33	D1	5000
Hexane, 2,4,4-trimethyl- (TIC)	TIC	**5720**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
Pentane, 2,3,4-trimethyl- (TIC)	TIC	**1790**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
2,3-Dimethyldecane (TIC)	TIC	**1320**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
Pentane, 2,3-dimethyl- (TIC)	TIC	**10400**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
Total T I C	TOTAL T I C	**93100**	5.00	mg/kg	10/05/11 13:33	D2	5000
Heptane, 2,2,4,6,6-pentamethyl- (TIC)	TIC	**1210**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
1-Butanol, 3,3-dimethyl- (TIC)	TIC	**1230**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
Hexane, 3-methyl- (TIC)	TIC	**13000**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
Pentane, 2,2,4-trimethyl- (TIC)	TIC	**1400**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
Decane, 2,2-dimethyl- (TIC)	TIC	**2040**	5.00	mg/kg	10/05/11 13:33	D1T4	5000
1-Cyano-2,3-epithiopropane (TIC)	TIC	**55000**	5.00	mg/kg	10/05/11 13:33	D1T4	5000

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
4-Bromofluorobenzene	460-00-4	103	%	58-152	10/05/11 13:33	
Dibromofluoromethane	1868-53-7	94	%	74-126	10/05/11 13:33	
1,2-Dichloroethane-D4	17060-07-0	112	%	80-120	10/05/11 13:33	
Toluene-D8	2037-26-5	93	%	73-132	10/05/11 13:33	

Project: Phoenix XENCO - Master Project

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Certificate of Analytical Results 428081

Southwest Research Institute, San Antonio, TX
16246.02.001

Sample Id: CL11-2512	**Matrix:** Solid	**Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-001	**Date Collected:** Sep-21-11 00:00	

Analytical Method: SVOCs by SW 8270C		**Prep Method:** SW3550
Tech: LUI		**% Moisture:**
Analyst: ZHO	**Date Prep:** Sep-27-11 08:45	**Basis:** Wet Weight
Seq Number: 871031		SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Acenaphthene	83-32-9	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Acenaphthylene	208-96-8	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Aniline (Phenylamine, Aminobenzene)	62-53-3	<1990	1990	mg/kg	10/02/11 08:40	D1	2991.03
Anthracene	120-12-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Benzo(a)anthracene	56-55-3	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Benzo(a)pyrene	50-32-8	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Benzo(b)fluoranthene	205-99-2	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Benzo(g,h,i)perylene	191-24-2	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Benzo(k)fluoranthene	207-08-9	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Benzoic Acid	65-85-0	<2990	2990	mg/kg	10/02/11 08:40	D1	2991.03
Benzyl Butyl Phthalate	85-68-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
bis(2-chloroethoxy) methane	111-91-1	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
bis(2-chloroethyl) ether	111-44-4	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
bis(2-chloroisopropyl) ether	108-60-1	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
bis(2-ethylhexyl) phthalate	117-81-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
4-Bromophenyl-phenylether	101-55-3	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
di-n-Butyl Phthalate	84-74-2	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
4-chloro-3-methylphenol	59-50-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
4-Chloroaniline	106-47-8	<1990	1990	mg/kg	10/02/11 08:40	D1	2991.03
2-Chloronaphthalene	91-58-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
2-Chlorophenol	95-57-8	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
4-Chlorophenyl Phenyl Ether	7005-72-3	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Chrysene	218-01-9	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Dibenz(a,h)anthracene	53-70-3	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Dibenzofuran	132-64-9	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
1,2-Dichlorobenzene	95-50-1	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
1,3-Dichlorobenzene	541-73-1	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
1,4-Dichlorobenzene	106-46-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
3,3-Dichlorobenzidine	91-94-1	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
2,4-Dichlorophenol	120-83-2	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
Diethyl Phthalate	84-66-2	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Dimethyl Phthalate	131-11-3	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
2,4-Dimethylphenol	105-67-9	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
4,6-dinitro-2-methyl phenol	534-52-1	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
2,4-Dinitrophenol	51-28-5	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
2,4-Dinitrotoluene	121-14-2	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
2,6-Dinitrotoluene	606-20-2	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Fluoranthene	206-44-0	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Fluorene	86-73-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Hexachlorobenzene	118-74-1	<499	499	mg/kg	10/02/11 08:40	D1	2991.03

Project: Phoenix XENCO - Master Project

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Certificate of Analytical Results 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Sample Id: CL11-2512	**Matrix:** Solid	**Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-001	**Date Collected:** Sep-21-11 00:00	

Analytical Method: SVOCs by SW 8270C			**Prep Method:** SW3550
Tech: LUI			**% Moisture:**
Analyst: ZHO		**Date Prep:** Sep-27-11 08:45	**Basis:** Wet Weight
Seq Number: 871031			SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Hexachlorobutadiene	87-68-3	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Hexachlorocyclopentadiene	77-47-4	<997	997	mg/kg	10/02/11 08:40	D1L2	2991.03
Hexachloroethane	67-72-1	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Indeno(1,2,3-c,d)Pyrene	193-39-5	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Isophorone	78-59-1	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
2-Methylnaphthalene	91-57-6	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
2-methylphenol	95-48-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
3&4-Methylphenol	15831-10-4	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
Naphthalene	91-20-3	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
4-Nitroaniline	100-01-6	<1990	1990	mg/kg	10/02/11 08:40	D1	2991.03
3-Nitroaniline	99-09-2	<1990	1990	mg/kg	10/02/11 08:40	D1	2991.03
2-Nitroaniline	88-74-4	<1990	1990	mg/kg	10/02/11 08:40	D1	2991.03
Nitrobenzene	98-95-3	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
2-Nitrophenol	88-75-5	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
4-Nitrophenol	100-02-7	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
N-Nitrosodi-n-Propylamine	621-64-7	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
N-Nitrosodiphenylamine	86-30-6	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
di-n-Octyl Phthalate	117-84-0	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Pentachlorophenol	87-86-5	<1340	1340	mg/kg	10/02/11 08:40	D1	2991.03
Phenanthrene	85-01-8	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Phenol	108-95-2	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Pyrene	129-00-0	<499	499	mg/kg	10/02/11 08:40	D1	2991.03
Pyridine	110-86-1	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
1,2,4-Trichlorobenzene	120-82-1	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
2,4,6-Trichlorophenol	88-06-2	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
2,4,5-Trichlorophenol	95-95-4	<997	997	mg/kg	10/02/11 08:40	D1	2991.03
Heptane, 2,2,3,3,5,6,6-heptamethyl- (TIC)	TIC	**1520**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Decane, 2,6,8-trimethyl-; 2,6,8-Trimethyldec (TIC	TIC	**1290**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Sulfurous acid, butyl 2-ethylhexyl ester (TIC)	TIC	**5910**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Nonane, 2-methyl- (TIC)	TIC	**2140**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Hexane, 2,2,3-trimethyl- (TIC)	TIC	**14800**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Decane, 3,3,7-trimethyl- (TIC)	TIC	**45200**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Pentane, 2,2,3,4-tetramethyl- (TIC)	TIC	**7610**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Cyclopentanecarboxylic acid, 3,5-difluorophe (TI	TIC	**1300**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Heptane, 4-ethyl-2,2,6,6-tetramethyl-; 4-Eth (TIC	TIC	**1900**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Tridecane, 6-methyl-; 6-Methyltridecane (TIC)	TIC	**1580**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Pentane, 2,3,4-trimethyl- (TIC)	TIC	**1360**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
2,2,6,6-Tetramethylheptane (TIC)	TIC	**54400**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Hexane, 3,3-dimethyl- (TIC)	TIC	**3170**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Nonane, 2,2,4,4,6,8,8-heptamethyl- (CAS); (TIC)	TIC	**20700**	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03

Project: Phoenix XENCO - Master Project

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Trans West Analytical Services, LLC

Certificate of Analytical Results 428081

Southwest Research Institute, San Antonio, TX
16246.02.001

Sample Id: CL11-2512 **Matrix:** Solid **Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-001 **Date Collected:** Sep-21-11 00:00

Analytical Method: SVOCs by SW 8270C **Prep Method:** SW3550
Tech: LUI **% Moisture:**
Analyst: ZHO **Date Prep:** Sep-27-11 08:45 **Basis:** Wet Weight
Seq Number: 871031 SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
2-Propanamine, N,N'-1,2-ethanediylidenebis[2 (T	TIC	7690	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Nonane, 2-methyl-; 2-Methylnonane (TIC)	TIC	2620	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Dodecane, 2,7,10-trimethyl-; 2,7,10-Trimethy (TI	TIC	6810	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Nonane, 2,2,4,4,6,8,8-heptamethyl- (TIC)	TIC	1730	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Undecane, 6-ethyl-; 6-Ethylundecane (TIC)	TIC	1340	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Hexane, 2,4,4-trimethyl- (TIC)	TIC	12600	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Undecane, 2,5-dimethyl-; 2,5-Dimethylundecan (T	TIC	1300	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Hexane, 2,2,5,5-tetramethyl-; Bineopentyl; 2 (TIC	TIC	7840	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Butane, 2,2,3,3-tetramethyl- (TIC)	TIC	14900	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Octane, 2,2,6-trimethyl-; 2,2,6-Trimethyloct (TIC	TIC	1970	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Decane, 3,3,5-trimethyl-; 3,3,5-Tr (TIC)	TIC	27000	99.7	mg/kg	10/02/11 08:40	D2T4	2991.03
Total T I C	TOTAL T I C	249000	99.7	mg/kg	10/02/11 08:40	D2	2991.03

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
2-Fluorobiphenyl	321-60-8	0	%	30-115	10/02/11 08:40	S8
2-Fluorophenol	367-12-4	0	%	25-121	10/02/11 08:40	S8
Nitrobenzene-d5	4165-60-0	0	%	23-120	10/02/11 08:40	S8
Phenol-d6	13127-88-3	0	%	24-113	10/02/11 08:40	S8
Terphenyl-D14	1718-51-0	0	%	18-137	10/02/11 08:40	S8
2,4,6-Tribromophenol	118-79-6	0	%	19-122	10/02/11 08:40	S8

Analytical Method: TPH by SW 8015D **Prep Method:** SW3550
Tech: LRA **% Moisture:**
Analyst: JAH **Date Prep:** Sep-30-11 10:39 **Basis:** Wet Weight
Seq Number: 871499 SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
C12-C28 Diesel Range Hydrocarbons	68334-30-5	7070	498	mg/kg	10/03/11 14:32	D2	298.81

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
Pentacosane	629-99-2	80	%	40-130	10/03/11 14:32	

Project: Phoenix XENCO - Master Project

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Certificate of Analytical Results 428081

Southwest Research Institute, San Antonio, TX
16246.02.001

Sample Id: CL11-2513 **Matrix:** Solid **Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-002 **Date Collected:** Sep-21-11 00:00

Analytical Method: Volatiles by SW 8260B **Prep Method:** SW5030B
Tech: CYE **% Moisture:**
Analyst: CYE **Date Prep:** Oct-05-11 12:47 **Basis:** Wet Weight
Seq Number: 871755 SUB: E871002

Dilution Analysis:
Seq#: 871755 Date Analyzed: 10/05/11 18:21 Date Prep: 10/05/11 17:35

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Benzene	71-43-2	**42.5**	25.0	mg/kg	10/05/11 13:56	D2	5000
Bromobenzene	108-86-1	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Bromochloromethane	74-97-5	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Bromodichloromethane	75-27-4	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Bromoform	75-25-2	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Methyl bromide	74-83-9	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
MTBE	1634-04-4	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
tert-Butylbenzene	98-06-6	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Sec-Butylbenzene	135-98-8	**543**	25.0	mg/kg	10/05/11 13:56	D2	5000
n-Butylbenzene	104-51-8	**1230**	250	mg/kg	10/05/11 18:21	D2	50000
Carbon Tetrachloride	56-23-5	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Chlorobenzene	108-90-7	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Chloroethane	75-00-3	<50.0	50.0	mg/kg	10/05/11 13:56	D1	5000
Chloroform	67-66-3	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Methyl Chloride	74-87-3	<50.0	50.0	mg/kg	10/05/11 13:56	D1	5000
2-Chlorotoluene	95-49-8	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
4-Chlorotoluene	106-43-4	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
p-Cymene (p-Isopropyltoluene)	99-87-6	**492**	25.0	mg/kg	10/05/11 13:56	D2	5000
1,2-Dibromo-3-Chloropropane	96-12-8	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Dibromochloromethane	124-48-1	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,2-Dibromoethane	106-93-4	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Methylene bromide	74-95-3	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,2-Dichlorobenzene	95-50-1	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,3-Dichlorobenzene	541-73-1	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,4-Dichlorobenzene	106-46-7	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Dichlorodifluoromethane	75-71-8	<25.0	25.0	mg/kg	10/05/11 13:56	D1L2	5000
1,2-Dichloroethane	107-06-2	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,1-Dichloroethane	75-34-3	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
trans-1,2-dichloroethylene	156-60-5	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
cis-1,2-Dichloroethylene	156-59-2	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,1-Dichloroethene	75-35-4	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
2,2-Dichloropropane	594-20-7	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,3-Dichloropropane	142-28-9	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,2-Dichloropropane	78-87-5	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
trans-1,3-dichloropropene	10061-02-6	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,1-Dichloropropene	563-58-6	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
cis-1,3-Dichloropropene	10061-01-5	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000

Project: Phoenix XENCO - Master Project

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Certificate of Analytical Results 428081

Southwest Research Institute, San Antonio, TX
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Sample Id: CL11-2513	**Matrix:** Solid	**Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-002	**Date Collected:** Sep-21-11 00:00	

Analytical Method: Volatiles by SW 8260B		**Prep Method:** SW5030B
Tech: CYE		**% Moisture:**
Analyst: CYE	**Date Prep:** Oct-05-11 12:47	**Basis:** Wet Weight
Seq Number: 871755		SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Ethylbenzene	100-41-4	**631**	25.0	mg/kg	10/05/11 13:56	D2	5000
Hexachlorobutadiene	87-68-3	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Isopropylbenzene	98-82-8	**255**	25.0	mg/kg	10/05/11 13:56	D2	5000
Naphthalene	91-20-3	**510**	50.0	mg/kg	10/05/11 13:56	D2	5000
Methylene Chloride	75-09-2	<100	100	mg/kg	10/05/11 13:56	D1	5000
n-Propylbenzene	103-65-1	**663**	25.0	mg/kg	10/05/11 13:56	D2	5000
Styrene	100-42-5	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,1,1,2-Tetrachloroethane	630-20-6	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,1,2,2-Tetrachloroethane	79-34-5	<25.0	25.0	mg/kg	10/05/11 13:56	D1L1	5000
Tetrachloroethylene	127-18-4	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Toluene	108-88-3	**558**	25.0	mg/kg	10/05/11 13:56	D2	5000
1,2,4-Trichlorobenzene	120-82-1	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,2,3-Trichlorobenzene	87-61-6	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,1,2-Trichloroethane	79-00-5	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,1,1-Trichloroethane	71-55-6	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Trichloroethylene	79-01-6	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
Trichlorofluoromethane	75-69-4	<25.0	25.0	mg/kg	10/05/11 13:56	D1	5000
1,2,3-Trichloropropane	96-18-4	<25.0	25.0	mg/kg	10/05/11 13:56	D1L1	5000
1,2,4-Trimethylbenzene	95-63-6	**5340**	250	mg/kg	10/05/11 18:21	D2	50000
1,3,5-Trimethylbenzene	108-67-8	**1220**	250	mg/kg	10/05/11 18:21	D2	50000
Vinyl Chloride	75-01-4	<10.0	10.0	mg/kg	10/05/11 13:56	D1	5000
o-Xylene	95-47-6	**1130**	250	mg/kg	10/05/11 18:21	D2	50000
m,p-Xylenes	1330-20-7	**1830**	500	mg/kg	10/05/11 18:21	D2	50000
Undecane (TIC)	TIC	**1380**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Decane, 2,3,4-trimethyl- (TIC)	TIC	**1470**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Decane, 3,3,5-trimethyl- (TIC)	TIC	**774**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Pentane, 2,3,4-trimethyl- (TIC)	TIC	**1350**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Pentane, 2,3-dimethyl- (TIC)	TIC	**679**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Octane, 5-ethyl-2-methyl- (TIC)	TIC	**631**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Dodecane, 2,2,4,9,11,11-hexamethyl- (TIC)	TIC	**1130**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Octane (TIC)	TIC	**835**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Butane, 2,2,3,3-tetramethyl- (TIC)	TIC	**1030**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Octane, 2,6-dimethyl- (TIC)	TIC	**935**	5.00	mg/kg	10/05/11 13:56	D1T4	5000
Total T I C	TOTAL T I C	**10200**	5.00	mg/kg	10/05/11 13:56	D2	5000

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
4-Bromofluorobenzene	460-00-4	136	%	58-152	10/05/11 13:56	
Dibromofluoromethane	1868-53-7	94	%	74-126	10/05/11 13:56	
1,2-Dichloroethane-D4	17060-07-0	108	%	80-120	10/05/11 13:56	
Toluene-D8	2037-26-5	126	%	73-132	10/05/11 13:56	

Project: Phoenix XENCO - Master Project

Certificate of Analytical Results 428081

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Sample Id: CL11-2513 **Matrix:** Solid **Date Received:** Sep-22-11 10:05

Lab Sample Id: 428081-002 **Date Collected:** Sep-21-11 00:00

Analytical Method: SVOCs by SW 8270C **Prep Method:** SW3550

Tech: LUI **% Moisture:**

Analyst: ZHO **Date Prep:** Sep-27-11 08:48 **Basis:** Wet Weight

Seq Number: 871031 SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Acenaphthene	83-32-9	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Acenaphthylene	208-96-8	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Aniline (Phenylamine, Aminobenzene)	62-53-3	<1980	1980	mg/kg	10/02/11 09:05	D1	2976.19
Anthracene	120-12-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Benzo(a)anthracene	56-55-3	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Benzo(a)pyrene	50-32-8	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Benzo(b)fluoranthene	205-99-2	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Benzo(g,h,i)perylene	191-24-2	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Benzo(k)fluoranthene	207-08-9	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Benzoic Acid	65-85-0	<2980	2980	mg/kg	10/02/11 09:05	D1	2976.19
Benzyl Butyl Phthalate	85-68-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
bis(2-chloroethoxy) methane	111-91-1	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
bis(2-chloroethyl) ether	111-44-4	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
bis(2-chloroisopropyl) ether	108-60-1	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
bis(2-ethylhexyl) phthalate	117-81-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
4-Bromophenyl-phenylether	101-55-3	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
di-n-Butyl Phthalate	84-74-2	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
4-chloro-3-methylphenol	59-50-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
4-Chloroaniline	106-47-8	<1980	1980	mg/kg	10/02/11 09:05	D1	2976.19
2-Chloronaphthalene	91-58-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
2-Chlorophenol	95-57-8	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
4-Chlorophenyl Phenyl Ether	7005-72-3	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Chrysene	218-01-9	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Dibenz(a,h)anthracene	53-70-3	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Dibenzofuran	132-64-9	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
1,2-Dichlorobenzene	95-50-1	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
1,3-Dichlorobenzene	541-73-1	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
1,4-Dichlorobenzene	106-46-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
3,3-Dichlorobenzidine	91-94-1	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
2,4-Dichlorophenol	120-83-2	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
Diethyl Phthalate	84-66-2	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Dimethyl Phthalate	131-11-3	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
2,4-Dimethylphenol	105-67-9	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
4,6-dinitro-2-methyl phenol	534-52-1	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
2,4-Dinitrophenol	51-28-5	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
2,4-Dinitrotoluene	121-14-2	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
2,6-Dinitrotoluene	606-20-2	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Fluoranthene	206-44-0	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Fluorene	86-73-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Hexachlorobenzene	118-74-1	<496	496	mg/kg	10/02/11 09:05	D1	2976.19

Project: Phoenix XENCO - Master Project

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Certificate of Analytical Results 428081

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Sample Id: CL11-2513 **Matrix:** Solid **Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-002 **Date Collected:** Sep-21-11 00:00

Analytical Method: SVOCs by SW 8270C **Prep Method:** SW3550
Tech: LUI **% Moisture:**
Analyst: ZHO **Date Prep:** Sep-27-11 08:48 **Basis:** Wet Weight
Seq Number: 871031 SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Hexachlorobutadiene	87-68-3	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Hexachlorocyclopentadiene	77-47-4	<992	992	mg/kg	10/02/11 09:05	D1L2	2976.19
Hexachloroethane	67-72-1	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Indeno(1,2,3-c,d)Pyrene	193-39-5	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Isophorone	78-59-1	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
2-Methylnaphthalene	91-57-6	**785**	496	mg/kg	10/02/11 09:05	D2	2976.19
2-methylphenol	95-48-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
3&4-Methylphenol	15831-10-4	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
Naphthalene	91-20-3	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
4-Nitroaniline	100-01-6	<1980	1980	mg/kg	10/02/11 09:05	D1	2976.19
3-Nitroaniline	99-09-2	<1980	1980	mg/kg	10/02/11 09:05	D1	2976.19
2-Nitroaniline	88-74-4	<1980	1980	mg/kg	10/02/11 09:05	D1	2976.19
Nitrobenzene	98-95-3	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
2-Nitrophenol	88-75-5	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
4-Nitrophenol	100-02-7	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
N-Nitrosodi-n-Propylamine	621-64-7	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
N-Nitrosodiphenylamine	86-30-6	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
di-n-Octyl Phthalate	117-84-0	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Pentachlorophenol	87-86-5	<1330	1330	mg/kg	10/02/11 09:05	D1	2976.19
Phenanthrene	85-01-8	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Phenol	108-95-2	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Pyrene	129-00-0	<496	496	mg/kg	10/02/11 09:05	D1	2976.19
Pyridine	110-86-1	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
1,2,4-Trichlorobenzene	120-82-1	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
2,4,6-Trichlorophenol	88-06-2	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
2,4,5-Trichlorophenol	95-95-4	<992	992	mg/kg	10/02/11 09:05	D1	2976.19
Undecane, 2,6-dimethyl- (TIC)	TIC	**2280**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Decane, 4-methyl- (TIC)	TIC	**2680**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
2,2,6,6-Tetramethylheptane (TIC)	TIC	**38000**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Tetradecane (TIC)	TIC	**6670**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Decane, 2-methyl- (TIC)	TIC	**3830**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
2-Propanamine, N,N'-1,2-ethanediylidenebis[2 (T	TIC	**2620**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Hexane, 2,4,4-trimethyl- (TIC)	TIC	**4080**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Benzene, 1-methyl-2-(1-methylethyl)- (TIC)	TIC	**3180**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Nonane (TIC)	TIC	**3690**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
2-N-HEXYL-1-D1-AZIRIDINE (TIC)	TIC	**20400**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Benzene, 1-ethyl-2-methyl- (CAS); (TIC)	TIC	**6150**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Hexane, 2,2,3-trimethyl-; 2,2,3-Trimethylhex (TI(	TIC	**3850**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Decane, 2,2,9-trimethyl-; 2,2,9-Trimethyldec (TIC	TIC	**3230**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Benzene, 1,2,4-trimethyl- (CAS); (TIC)	TIC	**2190**	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19

Project: Phoenix XENCO - Master Project

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Certificate of Analytical Results 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Sample Id: CL11-2513	**Matrix:** Solid	**Date Received:** Sep-22-11 10:05
Lab Sample Id: 428081-002	**Date Collected:** Sep-21-11 00:00	

Analytical Method: SVOCs by SW 8270C — **Prep Method:** SW3550
Tech: LUI — **% Moisture:**
Analyst: ZHO — **Date Prep:** Sep-27-11 08:48 — **Basis:** Wet Weight
Seq Number: 871031 — SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Tridecane, 7-methyl-; 7-Methyltridecane (TIC)	TIC	3330	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Undecane (TIC)	TIC	11500	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Dodecane, 2,7,10-trimethyl-; 2,7,10-Trimethy (TI	TIC	12100	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Nonane, 2,2,4,4,6,8,8-heptamethyl- (TIC)	TIC	6210	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Nonane, 3-methyl- (TIC)	TIC	2500	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Undecane, 2,4-dimethyl- (TIC)	TIC	2280	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Decane, 3-methyl- (TIC)	TIC	2920	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Dodecane (TIC)	TIC	8190	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Undecane, 5-methyl- (TIC)	TIC	3480	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Decane (TIC)	TIC	9280	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Sulfurous acid, butyl 2-ethylhexyl ester (TIC)	TIC	3820	99.2	mg/kg	10/02/11 09:05	D2T4	2976.19
Total T I C	TOTAL T I C	168000	99.2	mg/kg	10/02/11 09:05	D2	2976.19

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
2-Fluorobiphenyl	321-60-8	0	%	30-115	10/02/11 09:05	S8
2-Fluorophenol	367-12-4	0	%	25-121	10/02/11 09:05	S8
Nitrobenzene-d5	4165-60-0	0	%	23-120	10/02/11 09:05	S8
Phenol-d6	13127-88-3	0	%	24-113	10/02/11 09:05	S8
Terphenyl-D14	1718-51-0	100	%	18-137	10/02/11 09:05	
2,4,6-Tribromophenol	118-79-6	0	%	19-122	10/02/11 09:05	S8

Analytical Method: TPH by SW 8015D — **Prep Method:** SW3550
Tech: LRA — **% Moisture:**
Analyst: JAH — **Date Prep:** Sep-30-11 10:42 — **Basis:** Wet Weight
Seq Number: 871499 — SUB: E871002

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
C12-C28 Diesel Range Hydrocarbons	68334-30-5	15300	499	mg/kg	10/03/11 14:55	D2	299.4

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
Pentacosane	629-99-2	80	%	40-130	10/03/11 14:55	

Project: Phoenix XENCO - Master Project

Surrogate Recoveries

Project Name: 16246.02.001

Work Orders : 428081,

Project ID:

Method: Volatiles by SW 8260B **Matrix:** Solid **Prep Method:** SW5030B

Sample: 612341-1-BLK **Seq Number:** 871755 **Prep Date:** 10/05/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
4-Bromofluorobenzene	99	58-152	%	10/05/2011 12:48	
Dibromofluoromethane	112	74-126	%	10/05/2011 12:48	
1,2-Dichloroethane-D4	105	80-120	%	10/05/2011 12:48	
Toluene-D8	97	73-132	%	10/05/2011 12:48	

Method: Volatiles by SW 8260B **Matrix:** Solid **Prep Method:** SW5030B

Sample: 612341-1-BKS **Seq Number:** 871755 **Prep Date:** 10/05/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
4-Bromofluorobenzene	110	58-152	%	10/05/2011 16:09	
Dibromofluoromethane	92	74-126	%	10/05/2011 16:09	
1,2-Dichloroethane-D4	102	80-120	%	10/05/2011 16:09	
Toluene-D8	93	73-132	%	10/05/2011 16:09	

Method: Volatiles by SW 8260B **Matrix:** Solid **Prep Method:** SW5030B

Sample: 612341-1-BSD **Seq Number:** 871755 **Prep Date:** 10/05/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
4-Bromofluorobenzene	102	58-152	%	10/05/2011 16:32	
Dibromofluoromethane	99	74-126	%	10/05/2011 16:32	
1,2-Dichloroethane-D4	116	80-120	%	10/05/2011 16:32	
Toluene-D8	94	73-132	%	10/05/2011 16:32	

Method: SVOCs by SW 8270C **Matrix:** Solid **Prep Method:** SW3550

Sample: 611806-1-BLK **Seq Number:** 871031 **Prep Date:** 09/27/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
2-Fluorobiphenyl	82	30-115	%	09/27/2011 13:58	
2-Fluorophenol	89	25-121	%	09/27/2011 13:58	
Nitrobenzene-d5	91	23-120	%	09/27/2011 13:58	
Phenol-d6	92	24-113	%	09/27/2011 13:58	
Terphenyl-D14	83	18-137	%	09/27/2011 13:58	
2,4,6-Tribromophenol	88	19-122	%	09/27/2011 13:58	

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Surrogate Recoveries

Project Name: 16246.02.001

Work Orders : 428081, **Project ID:**

Method: SVOCs by SW 8270C **Matrix:** Solid **Prep Method:** SW3550
Sample: 611806-1-BKS **Seq Number:** 871031 **Prep Date:** 09/27/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
2-Fluorobiphenyl	73	30-115	%	09/27/2011 14:22	
2-Fluorophenol	81	25-121	%	09/27/2011 14:22	
Nitrobenzene-d5	80	23-120	%	09/27/2011 14:22	
Phenol-d6	90	24-113	%	09/27/2011 14:22	
Terphenyl-D14	77	18-137	%	09/27/2011 14:22	
2,4,6-Tribromophenol	85	19-122	%	09/27/2011 14:22	

Method: SVOCs by SW 8270C **Matrix:** Solid **Prep Method:** SW3550
Sample: 611806-1-BSD **Seq Number:** 871031 **Prep Date:** 09/27/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
2-Fluorobiphenyl	80	30-115	%	09/27/2011 14:47	
2-Fluorophenol	86	25-121	%	09/27/2011 14:47	
Nitrobenzene-d5	87	23-120	%	09/27/2011 14:47	
Phenol-d6	96	24-113	%	09/27/2011 14:47	
Terphenyl-D14	85	18-137	%	09/27/2011 14:47	
2,4,6-Tribromophenol	93	19-122	%	09/27/2011 14:47	

Method: SVOCs by SW 8270C **Matrix:** Solid **Prep Method:** SW3550
Sample: 428073-024 S **Seq Number:** 871031 **Prep Date:** 09/27/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
2-Fluorobiphenyl	77	30-115	%	09/27/2011 20:43	
2-Fluorophenol	78	25-121	%	09/27/2011 20:43	
Nitrobenzene-d5	82	23-120	%	09/27/2011 20:43	
Phenol-d6	92	24-113	%	09/27/2011 20:43	
Terphenyl-D14	89	18-137	%	09/27/2011 20:43	
2,4,6-Tribromophenol	95	19-122	%	09/27/2011 20:43	

Method: SVOCs by SW 8270C **Matrix:** Solid **Prep Method:** SW3550
Sample: 428073-024 SD **Seq Number:** 871031 **Prep Date:** 09/27/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
2-Fluorobiphenyl	78	30-115	%	09/27/2011 21:07	
2-Fluorophenol	81	25-121	%	09/27/2011 21:07	
Nitrobenzene-d5	84	23-120	%	09/27/2011 21:07	
Phenol-d6	96	24-113	%	09/27/2011 21:07	
Terphenyl-D14	91	18-137	%	09/27/2011 21:07	
2,4,6-Tribromophenol	96	19-122	%	09/27/2011 21:07	

Surrogate Recoveries

Project Name: 16246.02.001

Work Orders : 428081,

Project ID:

Method: TPH by SW 8015D **Matrix:** Solid **Prep Method:** SW3550

Sample: 612078-1-BLK **Seq Number:** 871499 **Prep Date:** 09/30/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
Pentacosane	65	40-130	%	10/03/2011 11:38	

Method: TPH by SW 8015D **Matrix:** Solid **Prep Method:** SW3550

Sample: 612078-1-BKS **Seq Number:** 871499 **Prep Date:** 09/30/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
Pentacosane	73	40-130	%	10/03/2011 12:01	

Method: TPH by SW 8015D **Matrix:** Solid **Prep Method:** SW3550

Sample: 612078-1-BSD **Seq Number:** 871499 **Prep Date:** 09/30/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
Pentacosane	71	40-130	%	10/03/2011 12:24	

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QC Summary 428081

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Analytical Method: **Volatiles by SW 8260B** | Prep Method: SW5030B
Seq Number: 871755 | Matrix: Solid | Date Prep: 10/05/2011
MB Sample Id: 612341-1-BLK | LCS Sample Id: 612341-1-BKS | LCSD Sample Id: 612341-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Benzene	<0.00500	0.05	0.0440	88	0.0472	94	66-142	7	21	mg/kg	10/05/11 16:09	
Bromobenzene	<0.00500	0.05	0.0559	112	0.0578	116	75-125	3	25	mg/kg	10/05/11 16:09	
Bromochloromethane	<0.00500	0.05	0.0445	89	0.0492	98	73-125	10	20	mg/kg	10/05/11 16:09	
Bromodichloromethane	<0.00500	0.05	0.0459	92	0.0462	92	75-125	1	20	mg/kg	10/05/11 16:09	
Bromoform	<0.00500	0.05	0.0445	89	0.0412	82	75-125	8	20	mg/kg	10/05/11 16:09	
Methyl bromide	<0.00500	0.05	0.0410	82	0.0477	95	65-135	15	20	mg/kg	10/05/11 16:09	
MTBE	<0.00500	0.05	0.0551	110	0.0576	115	65-135	4	20	mg/kg	10/05/11 16:09	
tert-Butylbenzene	<0.00500	0.05	0.0555	111	0.0560	112	75-125	1	25	mg/kg	10/05/11 16:09	
Sec-Butylbenzene	<0.00500	0.05	0.0525	105	0.0548	110	75-125	4	25	mg/kg	10/05/11 16:09	
n-Butylbenzene	<0.00500	0.05	0.0506	101	0.0532	106	75-125	5	25	mg/kg	10/05/11 16:09	
Carbon Tetrachloride	<0.00500	0.05	0.0405	81	0.0460	92	62-125	13	20	mg/kg	10/05/11 16:09	
Chlorobenzene	<0.00500	0.05	0.0481	96	0.0477	95	60-133	1	21	mg/kg	10/05/11 16:09	
Chloroethane	<0.0100	0.05	0.0389	78	0.0406	81	65-135	4	20	mg/kg	10/05/11 16:09	
Chloroform	<0.00500	0.05	0.0438	88	0.0470	94	74-125	7	20	mg/kg	10/05/11 16:09	
Methyl Chloride	<0.0100	0.05	0.0330	66	0.0383	77	65-135	15	20	mg/kg	10/05/11 16:09	
2-Chlorotoluene	<0.00500	0.05	0.0540	108	0.0542	108	73-125	0	25	mg/kg	10/05/11 16:09	
4-Chlorotoluene	<0.00500	0.05	0.0548	110	0.0550	110	74-125	0	25	mg/kg	10/05/11 16:09	
p-Cymene (p-Isopropyltoluene)	<0.00500	0.05	0.0541	108	0.0556	111	75-125	3	25	mg/kg	10/05/11 16:09	
1,2-Dibromo-3-Chloropropane	<0.00500	0.05	0.0602	120	0.0580	116	59-125	4	28	mg/kg	10/05/11 16:09	
Dibromochloromethane	<0.00500	0.05	0.0534	107	0.0491	98	73-125	8	25	mg/kg	10/05/11 16:09	
1,2-Dibromoethane	<0.00500	0.05	0.0582	116	0.0508	102	73-125	14	20	mg/kg	10/05/11 16:09	
Methylene bromide	<0.00500	0.05	0.0502	100	0.0491	98	69-127	2	23	mg/kg	10/05/11 16:09	
1,2-Dichlorobenzene	<0.00500	0.05	0.0512	102	0.0535	107	75-125	4	25	mg/kg	10/05/11 16:09	
1,3-Dichlorobenzene	<0.00500	0.05	0.0540	108	0.0545	109	75-125	1	25	mg/kg	10/05/11 16:09	
1,4-Dichlorobenzene	<0.00500	0.05	0.0529	106	0.0541	108	75-125	2	25	mg/kg	10/05/11 16:09	
Dichlorodifluoromethane	<0.00500	0.05	0.0275	55	0.0318	64	65-135	15	23	mg/kg	10/05/11 16:09	L2
1,2-Dichloroethane	<0.00500	0.05	0.0478	96	0.0467	93	68-127	2	20	mg/kg	10/05/11 16:09	
1,1-Dichloroethane	<0.00500	0.05	0.0442	88	0.0496	99	72-125	12	20	mg/kg	10/05/11 16:09	
trans-1,2-dichloroethylene	<0.00500	0.05	0.0411	82	0.0456	91	75-125	10	20	mg/kg	10/05/11 16:09	
cis-1,2-Dichloroethylene	<0.00500	0.05	0.0421	84	0.0474	95	75-125	12	20	mg/kg	10/05/11 16:09	
1,1-Dichloroethene	<0.00500	0.05	0.0414	83	0.0470	94	59-172	13	22	mg/kg	10/05/11 16:09	
2,2-Dichloropropane	<0.00500	0.05	0.0436	87	0.0505	101	75-125	15	25	mg/kg	10/05/11 16:09	
1,3-Dichloropropane	<0.00500	0.05	0.0567	113	0.0519	104	75-125	9	25	mg/kg	10/05/11 16:09	
1,2-Dichloropropane	<0.00500	0.05	0.0466	93	0.0479	96	74-125	3	20	mg/kg	10/05/11 16:09	
trans-1,3-dichloropropene	<0.00500	0.05	0.0487	97	0.0495	99	66-125	2	20	mg/kg	10/05/11 16:09	
1,1-Dichloropropene	<0.00500	0.05	0.0465	93	0.0482	96	75-125	4	25	mg/kg	10/05/11 16:09	
cis-1,3-Dichloropropene	<0.00500	0.05	0.0506	101	0.0496	99	74-125	2	20	mg/kg	10/05/11 16:09	
Ethylbenzene	<0.00500	0.05	0.0489	98	0.0481	96	75-125	2	20	mg/kg	10/05/11 16:09	
Hexachlorobutadiene	<0.00500	0.05	0.0495	99	0.0515	103	75-125	4	25	mg/kg	10/05/11 16:09	
Isopropylbenzene	<0.00500	0.05	0.0532	106	0.0548	110	75-125	3	25	mg/kg	10/05/11 16:09	
Naphthalene	<0.0100	0.05	0.0583	117	0.0580	116	70-130	1	20	mg/kg	10/05/11 16:09	
Methylene Chloride	<0.0200	0.05	0.0460	92	0.0515	103	75-125	11	35	mg/kg	10/05/11 16:09	
n-Propylbenzene	<0.00500	0.05	0.0514	103	0.0557	111	75-125	8	25	mg/kg	10/05/11 16:09	
Styrene	<0.00500	0.05	0.0508	102	0.0503	101	75-125	1	51	mg/kg	10/05/11 16:09	
1,1,1,2-Tetrachloroethane	<0.00500	0.05	0.0523	105	0.0486	97	72-125	7	20	mg/kg	10/05/11 16:09	
1,1,2,2-Tetrachloroethane	<0.00500	0.05	0.0636	127	0.0568	114	74-125	11	31	mg/kg	10/05/11 16:09	L1

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QC Summary 428081

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16246.02.001

Analytical Method: **Volatiles by SW 8260B** Prep Method: SW5030B
Seq Number: 871755 Matrix: Solid Date Prep: 10/05/2011
MB Sample Id: 612341-1-BLK LCS Sample Id: 612341-1-BKS LCSD Sample Id: 612341-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Tetrachloroethylene	<0.00500	0.05	0.0496	99	0.0485	97	71-125	2	20	mg/kg	10/05/11 16:09	
Toluene	<0.00500	0.05	0.0440	88	0.0456	91	59-139	4	21	mg/kg	10/05/11 16:09	
1,2,4-Trichlorobenzene	<0.00500	0.05	0.0516	103	0.0544	109	75-135	5	25	mg/kg	10/05/11 16:09	
1,2,3-Trichlorobenzene	<0.00500	0.05	0.0531	106	0.0552	110	75-137	4	25	mg/kg	10/05/11 16:09	
1,1,2-Trichloroethane	<0.00500	0.05	0.0486	97	0.0493	99	75-127	1	20	mg/kg	10/05/11 16:09	
1,1,1-Trichloroethane	<0.00500	0.05	0.0401	80	0.0467	93	75-125	15	20	mg/kg	10/05/11 16:09	
Trichloroethylene	<0.00500	0.05	0.0467	93	0.0480	96	62-137	3	24	mg/kg	10/05/11 16:09	
Trichlorofluoromethane	<0.00500	0.05	0.0405	81	0.0443	89	67-125	9	20	mg/kg	10/05/11 16:09	
1,2,3-Trichloropropane	<0.00500	0.05	0.0652	130	0.0638	128	75-125	2	20	mg/kg	10/05/11 16:09	L1
1,2,4-Trimethylbenzene	<0.00500	0.05	0.0557	111	0.0566	113	75-125	2	25	mg/kg	10/05/11 16:09	
1,3,5-Trimethylbenzene	<0.00500	0.05	0.0551	110	0.0561	112	70-130	2	25	mg/kg	10/05/11 16:09	
Vinyl Chloride	<0.00200	0.05	0.0388	78	0.0436	87	65-135	12	20	mg/kg	10/05/11 16:09	
o-Xylene	<0.00500	0.05	0.0497	99	0.0493	99	75-125	1	20	mg/kg	10/05/11 16:09	
m,p-Xylenes	<0.0100	0.1	0.0966	97	0.0963	96	75-125	0	20	mg/kg	10/05/11 16:09	

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QC Summary 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Analytical Method: **SVOCs by SW 8270C** Prep Method: SW3550
Seq Number: 871031 Matrix: Solid Date Prep: 09/27/2011
MB Sample Id: 611806-1-BLK LCS Sample Id: 611806-1-BKS LCSD Sample Id: 611806-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Acenaphthene	<0.166	1.66	1.24	75	1.28	77	41-134	3	25	mg/kg	09/27/11 14:22	
Acenaphthylene	<0.166	1.66	1.27	77	1.30	78	65-135	2	25	mg/kg	09/27/11 14:22	
Aniline (Phenylamine, Aminobenzene)	<0.665	1.66	1.29	78	1.32	80	2-145	2	25	mg/kg	09/27/11 14:22	
Anthracene	<0.166	1.66	1.30	78	1.35	81	65-135	4	25	mg/kg	09/27/11 14:22	
Benzo(a)anthracene	<0.166	1.66	1.33	80	1.37	83	44-126	3	25	mg/kg	09/27/11 14:22	
Benzo(a)pyrene	<0.166	1.66	1.33	80	1.38	83	65-135	4	25	mg/kg	09/27/11 14:22	
Benzo(b)fluoranthene	<0.166	1.66	1.34	81	1.47	89	65-135	9	25	mg/kg	09/27/11 14:22	
Benzo(g,h,i)perylene	<0.166	1.66	1.38	83	1.41	85	65-135	2	25	mg/kg	09/27/11 14:22	
Benzo(k)fluoranthene	<0.166	1.66	1.24	75	1.19	72	25-125	4	25	mg/kg	09/27/11 14:22	
Benzoic Acid	<0.997	4.99	3.21	64	3.47	70	50-125	8	25	mg/kg	09/27/11 14:22	
bis(2-chloroethoxy) methane	<0.166	1.66	1.50	90	1.52	92	65-135	1	25	mg/kg	09/27/11 14:22	
bis(2-chloroethyl) ether	<0.166	1.66	1.30	78	1.33	80	65-135	2	25	mg/kg	09/27/11 14:22	
bis(2-chloroisopropyl) ether	<0.166	1.66	1.54	93	1.59	96	65-135	3	25	mg/kg	09/27/11 14:22	
bis(2-ethylhexyl) phthalate	<0.166	1.66	1.44	87	1.51	91	65-135	5	25	mg/kg	09/27/11 14:22	
4-Bromophenyl-phenylether	<0.166	1.66	1.29	78	1.34	81	65-135	4	25	mg/kg	09/27/11 14:22	
di-n-Butyl Phthalate	<0.166	1.66	1.39	84	1.47	89	65-135	6	25	mg/kg	09/27/11 14:22	
4-chloro-3-methylphenol	<0.166	1.66	1.39	84	1.44	87	28-134	4	25	mg/kg	09/27/11 14:22	
4-Chloroaniline	<0.665	1.66	1.30	78	1.35	81	4-149	4	25	mg/kg	09/27/11 14:22	
2-Chloronaphthalene	<0.166	1.66	1.16	70	1.19	72	65-135	3	25	mg/kg	09/27/11 14:22	
2-Chlorophenol	<0.166	1.66	1.29	78	1.30	78	25-140	1	25	mg/kg	09/27/11 14:22	
4-Chlorophenyl Phenyl Ether	<0.166	1.66	1.26	76	1.31	79	65-135	4	25	mg/kg	09/27/11 14:22	
Chrysene	<0.166	1.66	1.29	78	1.34	81	65-135	4	25	mg/kg	09/27/11 14:22	
Dibenz(a,h)anthracene	<0.166	1.66	1.31	79	1.34	81	65-135	2	25	mg/kg	09/27/11 14:22	
Dibenzofuran	<0.166	1.66	1.27	77	1.31	79	65-135	3	25	mg/kg	09/27/11 14:22	
1,2-Dichlorobenzene	<0.166	1.66	1.26	76	1.27	77	65-135	1	25	mg/kg	09/27/11 14:22	
1,3-Dichlorobenzene	<0.166	1.66	1.24	75	1.25	75	65-135	1	25	mg/kg	09/27/11 14:22	
1,4-Dichlorobenzene	<0.166	1.66	1.24	75	1.24	75	36-134	0	25	mg/kg	09/27/11 14:22	
3,3-Dichlorobenzidine	<0.332	1.66	1.34	81	1.39	84	20-140	4	25	mg/kg	09/27/11 14:22	
2,4-Dichlorophenol	<0.332	1.66	1.33	80	1.36	82	65-135	2	25	mg/kg	09/27/11 14:22	
Diethyl Phthalate	0.334	1.66	1.58	95	1.63	98	37-125	3	25	mg/kg	09/27/11 14:22	
2,4-Dimethylphenol	<0.166	1.66	1.37	83	1.40	84	65-135	2	25	mg/kg	09/27/11 14:22	
4,6-dinitro-2-methyl phenol	<0.332	1.66	1.30	78	1.33	80	65-135	2	25	mg/kg	09/27/11 14:22	
2,4-Dinitrophenol	<0.332	1.66	1.23	74	1.26	76	65-135	2	25	mg/kg	09/27/11 14:22	
2,4-Dinitrotoluene	<0.166	1.66	1.42	86	1.48	89	40-130	4	25	mg/kg	09/27/11 14:22	
2,6-Dinitrotoluene	<0.166	1.66	1.31	79	1.36	82	28-89	4	25	mg/kg	09/27/11 14:22	
Fluoranthene	<0.166	1.66	1.33	80	1.39	84	65-135	4	25	mg/kg	09/27/11 14:22	
Fluorene	<0.166	1.66	1.27	77	1.33	80	65-135	5	25	mg/kg	09/27/11 14:22	
Hexachlorobenzene	<0.166	1.66	1.25	75	1.30	78	65-135	4	25	mg/kg	09/27/11 14:22	
Hexachlorobutadiene	<0.166	1.66	1.26	76	1.27	77	65-135	1	25	mg/kg	09/27/11 14:22	
Hexachlorocyclopentadiene	<0.332	1.66	1.05	63	1.05	63	65-135	0	25	mg/kg	09/27/11 14:22	L2
Hexachloroethane	<0.166	1.66	1.33	80	1.36	82	65-135	2	25	mg/kg	09/27/11 14:22	
Indeno(1,2,3-c,d)Pyrene	<0.166	1.66	1.34	81	1.39	84	65-135	4	25	mg/kg	09/27/11 14:22	
Isophorone	<0.166	1.66	1.35	81	1.39	84	65-135	3	25	mg/kg	09/27/11 14:22	
2-Methylnaphthalene	<0.166	1.66	0.937	56	0.964	58	25-175	3	25	mg/kg	09/27/11 14:22	
2-methylphenol	<0.166	1.66	1.31	79	1.34	81	65-135	2	25	mg/kg	09/27/11 14:22	
3&4-Methylphenol	<0.332	1.66	1.32	80	1.37	83	65-135	4	25	mg/kg	09/27/11 14:22	

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QC Summary 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Analytical Method: **SVOCs by SW 8270C** Prep Method: SW3550

Seq Number: 871031 Matrix: Solid Date Prep: 09/27/2011

MB Sample Id: 611806-1-BLK LCS Sample Id: 611806-1-BKS LCSD Sample Id: 611806-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Naphthalene	<0.166	1.66	1.25	75	1.27	77	65-135	2	25	mg/kg	09/27/11 14:22	
4-Nitroaniline	<0.665	1.66	1.36	82	1.42	86	65-135	4	25	mg/kg	09/27/11 14:22	
3-Nitroaniline	<0.665	1.66	1.34	81	1.40	84	65-135	4	25	mg/kg	09/27/11 14:22	
2-Nitroaniline	<0.665	1.66	1.52	92	1.58	95	65-135	4	25	mg/kg	09/27/11 14:22	
Nitrobenzene	<0.166	1.66	1.45	87	1.47	89	65-135	1	25	mg/kg	09/27/11 14:22	
2-Nitrophenol	<0.166	1.66	1.32	80	1.34	81	65-135	2	25	mg/kg	09/27/11 14:22	
4-Nitrophenol	<0.332	1.66	1.61	97	1.66	100	13-106	3	25	mg/kg	09/27/11 14:22	
N-Nitrosodi-n-Propylamine	<0.166	1.66	1.37	83	1.42	86	53-130	4	25	mg/kg	09/27/11 14:22	
N-Nitrosodiphenylamine	<0.166	1.66	1.30	78	1.35	81	65-135	4	25	mg/kg	09/27/11 14:22	
di-n-Octyl Phthalate	<0.166	1.66	1.42	86	1.48	89	65-135	4	25	mg/kg	09/27/11 14:22	
Pentachlorophenol	<0.445	1.66	0.986	59	1.03	62	14-111	4	25	mg/kg	09/27/11 14:22	
Phenanthrene	<0.166	1.66	1.28	77	1.33	80	65-135	4	25	mg/kg	09/27/11 14:22	
Phenol	<0.166	1.66	1.34	81	1.37	83	27-127	2	25	mg/kg	09/27/11 14:22	
Pyrene	<0.166	1.66	1.29	78	1.34	81	41-144	4	25	mg/kg	09/27/11 14:22	
Pyridine	<0.332	1.66	1.13	68	1.06	64	39-98	6	25	mg/kg	09/27/11 14:22	
1,2,4-Trichlorobenzene	<0.332	1.66	1.24	75	1.25	75	37-133	1	25	mg/kg	09/27/11 14:22	
2,4,6-Trichlorophenol	<0.332	1.66	1.36	82	1.41	85	65-135	4	25	mg/kg	09/27/11 14:22	
2,4,5-Trichlorophenol	<0.332	1.66	1.17	70	1.21	73	65-135	3	25	mg/kg	09/27/11 14:22	

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Trans West Analytical Services, LLC

QC Summary 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Analytical Method: **SVOCs by SW 8270C** Prep Method: SW3550

Seq Number: 871031 Matrix: Solid Date Prep: 09/27/2011

Parent Sample Id: 428073-024 MS Sample Id: 428073-024 S MSD Sample Id: 428073-024 SD

Parameter	Parent Result	Spike Amount	MS Result	MS %Rec	MSD Result	MSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Acenaphthene	<0.167	3.33	2.33	70	2.40	72	41-134	3	25	mg/kg	09/27/11 20:43	
Acenaphthylene	<0.167	3.33	2.29	69	2.37	71	65-135	3	25	mg/kg	09/27/11 20:43	
Aniline (Phenylamine, Aminobenzene)	<0.666	3.33	2.33	70	2.40	72	2-145	3	25	mg/kg	09/27/11 20:43	
Anthracene	<0.167	3.33	2.46	74	2.48	75	65-135	1	25	mg/kg	09/27/11 20:43	
Benzo(a)anthracene	<0.167	3.33	2.66	80	2.76	83	44-126	4	25	mg/kg	09/27/11 20:43	
Benzo(a)pyrene	<0.167	3.33	2.57	77	2.64	80	65-135	3	25	mg/kg	09/27/11 20:43	
Benzo(b)fluoranthene	<0.167	3.33	3.03	91	3.26	98	65-135	7	25	mg/kg	09/27/11 20:43	
Benzo(g,h,i)perylene	<0.167	3.33	2.12	64	2.25	68	65-135	6	25	mg/kg	09/27/11 20:43	M2
Benzo(k)fluoranthene	<0.167	3.33	2.18	65	2.19	66	25-125	0	25	mg/kg	09/27/11 20:43	
Benzoic Acid	<0.999	9.99	12.4	124	10.8	108	50-125	14	25	mg/kg	09/27/11 20:43	
bis(2-chloroethoxy) methane	<0.167	3.33	2.70	81	2.80	84	65-135	4	25	mg/kg	09/27/11 20:43	
bis(2-chloroethyl) ether	<0.167	3.33	2.47	74	2.56	77	65-135	4	25	mg/kg	09/27/11 20:43	
bis(2-chloroisopropyl) ether	<0.167	3.33	2.81	84	2.94	89	65-135	5	25	mg/kg	09/27/11 20:43	
bis(2-ethylhexyl) phthalate	<0.167	3.33	2.85	86	2.99	90	65-135	5	25	mg/kg	09/27/11 20:43	
4-Bromophenyl-phenylether	<0.167	3.33	2.56	77	2.65	80	65-135	3	25	mg/kg	09/27/11 20:43	
di-n-Butyl Phthalate	<0.167	3.33	2.30	69	2.36	71	65-135	3	25	mg/kg	09/27/11 20:43	
4-chloro-3-methylphenol	<0.167	3.33	2.67	80	2.83	85	28-134	6	25	mg/kg	09/27/11 20:43	
4-Chloroaniline	<0.666	3.33	2.26	68	2.33	70	4-149	3	25	mg/kg	09/27/11 20:43	
2-Chloronaphthalene	<0.167	3.33	1.67	50	1.71	52	65-135	2	25	mg/kg	09/27/11 20:43	M2
2-Chlorophenol	<0.167	3.33	2.39	72	2.54	77	25-140	6	25	mg/kg	09/27/11 20:43	
4-Chlorophenyl Phenyl Ether	<0.167	3.33	2.35	71	2.43	73	65-135	3	25	mg/kg	09/27/11 20:43	
Chrysene	<0.167	3.33	2.46	74	2.50	75	65-135	2	25	mg/kg	09/27/11 20:43	
Dibenz(a,h)anthracene	<0.167	3.33	2.13	64	2.19	66	65-135	3	25	mg/kg	09/27/11 20:43	M2
Dibenzofuran	<0.167	3.33	2.34	70	2.40	72	65-135	3	25	mg/kg	09/27/11 20:43	
1,2-Dichlorobenzene	<0.167	3.33	2.33	70	2.45	74	65-135	5	25	mg/kg	09/27/11 20:43	
1,3-Dichlorobenzene	<0.167	3.33	2.29	69	2.38	72	65-135	4	25	mg/kg	09/27/11 20:43	
1,4-Dichlorobenzene	<0.167	3.33	2.24	67	2.36	71	36-134	5	25	mg/kg	09/27/11 20:43	
3,3-Dichlorobenzidine	<0.333	3.33	2.53	76	2.61	79	20-140	3	25	mg/kg	09/27/11 20:43	
2,4-Dichlorophenol	<0.333	3.33	2.58	77	2.71	82	65-135	5	25	mg/kg	09/27/11 20:43	
Diethyl Phthalate	<0.167	3.33	2.43	73	2.49	75	37-125	2	25	mg/kg	09/27/11 20:43	
2,4-Dimethylphenol	<0.167	3.33	2.57	77	2.67	80	65-135	4	25	mg/kg	09/27/11 20:43	
4,6-dinitro-2-methyl phenol	<0.333	3.33	1.61	48	1.69	51	65-135	5	25	mg/kg	09/27/11 20:43	M2
2,4-Dinitrophenol	<0.333	3.33	1.48	44	1.48	45	65-135	0	25	mg/kg	09/27/11 20:43	M2
2,4-Dinitrotoluene	<0.167	3.33	2.64	79	2.71	82	40-130	3	25	mg/kg	09/27/11 20:43	
2,6-Dinitrotoluene	<0.167	3.33	2.45	74	2.57	77	28-89	5	25	mg/kg	09/27/11 20:43	
Fluoranthene	<0.167	3.33	2.49	75	2.54	77	65-135	2	25	mg/kg	09/27/11 20:43	
Fluorene	<0.167	3.33	2.36	71	2.42	73	65-135	3	25	mg/kg	09/27/11 20:43	
Hexachlorobenzene	<0.167	3.33	2.54	76	2.63	79	65-135	3	25	mg/kg	09/27/11 20:43	
Hexachlorobutadiene	<0.167	3.33	2.30	69	2.37	71	65-135	3	25	mg/kg	09/27/11 20:43	
Hexachlorocyclopentadiene	<0.333	3.33	0.948	28	0.980	30	65-135	3	25	mg/kg	09/27/11 20:43	M2
Hexachloroethane	<0.167	3.33	1.98	59	2.11	64	65-135	6	25	mg/kg	09/27/11 20:43	M2
Indeno(1,2,3-c,d)Pyrene	<0.167	3.33	2.14	64	2.22	67	65-135	4	25	mg/kg	09/27/11 20:43	M2
Isophorone	<0.167	3.33	2.55	77	2.66	80	65-135	4	25	mg/kg	09/27/11 20:43	
2-Methylnaphthalene	<0.167	3.33	1.75	53	1.84	55	25-175	5	25	mg/kg	09/27/11 20:43	
2-methylphenol	<0.167	3.33	2.65	80	2.81	85	65-135	6	25	mg/kg	09/27/11 20:43	
3&4-Methylphenol	<0.333	3.33	2.49	75	2.66	80	65-135	7	25	mg/kg	09/27/11 20:43	

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QC Summary 428081

Southwest Research Institute, San Antonio, TX

16246.02.001

Analytical Method: **SVOCs by SW 8270C** Prep Method: SW3550
Seq Number: 871031 Matrix: Solid Date Prep: 09/27/2011
Parent Sample Id: 428073-024 MS Sample Id: 428073-024 S MSD Sample Id: 428073-024 SD

Parameter	Parent Result	Spike Amount	MS Result	MS %Rec	MSD Result	MSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Naphthalene	<0.167	3.33	2.14	64	2.22	67	65-135	4	25	mg/kg	09/27/11 20:43	M2
4-Nitroaniline	<0.666	3.33	2.49	75	2.56	77	65-135	3	25	mg/kg	09/27/11 20:43	
3-Nitroaniline	<0.666	3.33	2.47	74	2.52	76	65-135	2	25	mg/kg	09/27/11 20:43	
2-Nitroaniline	<0.666	3.33	2.91	87	2.98	90	65-135	2	25	mg/kg	09/27/11 20:43	
Nitrobenzene	<0.167	3.33	2.86	86	3.01	91	65-135	5	25	mg/kg	09/27/11 20:43	
2-Nitrophenol	<0.167	3.33	2.52	76	2.64	80	65-135	5	25	mg/kg	09/27/11 20:43	
4-Nitrophenol	<0.333	3.33	3.08	92	3.01	91	13-106	2	25	mg/kg	09/27/11 20:43	
N-Nitrosodi-n-Propylamine	<0.167	3.33	2.54	76	2.66	80	53-130	5	25	mg/kg	09/27/11 20:43	
N-Nitrosodiphenylamine	<0.167	3.33	2.41	72	2.49	75	65-135	3	25	mg/kg	09/27/11 20:43	
di-n-Octyl Phthalate	<0.167	3.33	2.87	86	3.11	94	65-135	8	25	mg/kg	09/27/11 20:43	
Pentachlorophenol	<0.446	3.33	2.28	68	2.27	68	14-111	0	25	mg/kg	09/27/11 20:43	
Phenanthrene	<0.167	3.33	2.43	73	2.50	75	65-135	3	25	mg/kg	09/27/11 20:43	
Phenol	<0.167	3.33	2.49	75	2.65	80	27-127	6	25	mg/kg	09/27/11 20:43	
Pyrene	<0.167	3.33	2.69	81	2.85	86	41-144	6	25	mg/kg	09/27/11 20:43	
Pyridine	<0.333	3.33	1.70	51	1.65	50	39-98	3	25	mg/kg	09/27/11 20:43	
1,2,4-Trichlorobenzene	<0.333	3.33	2.34	70	2.44	73	37-133	4	25	mg/kg	09/27/11 20:43	
2,4,6-Trichlorophenol	<0.333	3.33	2.74	82	2.85	86	65-135	4	25	mg/kg	09/27/11 20:43	
2,4,5-Trichlorophenol	<0.333	3.33	2.39	72	2.39	72	65-135	0	25	mg/kg	09/27/11 20:43	

Analytical Method: **TPH by SW 8015D** Prep Method: SW3550
Seq Number: 871499 Matrix: Solid Date Prep: 09/30/2011
MB Sample Id: 612078-1-BLK LCS Sample Id: 612078-1-BKS LCSD Sample Id: 612078-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
C12-C28 Diesel Range Hydrocarbons	<1.67	33.3	27.8	83	29.6	89	70-130	6	35	mg/kg	10/03/11 12:01	

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Work Order No: 428081

Page ______ of ______

Project Manager:	Scott Hutzler	Bill to: (if different)	
Company Name:	Southwest Research Inst.	Company Name:	
Address:	9503 W. Commerce	Address:	
City, State ZIP:	San Antonio, TX 78227	City, State ZIP:	
Phone:	210-684-5111	Email:	

Work Order Comments

Project Name:	
Project Number:	16246.05.001
P.O. Number:	
Sampler's Name:	

SAMPLE RECEIPT

Temperature (°C):	25.1	Temp Blank Present:	N
Received Intact:	Yes No N/A	~~Wet Ice / Blue Ice~~ No ice	
Cooler Custody Seals:	Yes No N/A	Total Containers:	2
Sample Custody Seals:	Yes No N/A		

ANALYSIS REQUEST (PLEASE CHECK METHOD NUMBER)

Sample Identification	Matrix	Date Sampled	Time Sampled	Lab ID	Number of Containers	Volatile Organics 8260B / 624 / 524.2	Acrolein / Acrylonitrile 8260B / 624 / 2-CEVE	Semi-Volatile Organics 8270C / 625	Organochlorine Pesticides 8081A / 608	Oil & Grease (1664-HEM) / TPH (1664-HEM-SGT)	Metals (See Below) Total / Hardness / Ca Hardness	Metals (See Below) Dissolved / TCLP	Total Hexavalent Cr / Dissolved Hexavalent Cr	Total Cyanide / Amenable (Free) Cyanide	BOD	pH / Cond. / Alk / TDS / TSS / Cl / SO4 / F / Ortho-P	NO2 / NO3 (300.0)	NO2+NO3 (353.2)	TKN / NH3 / COD / Total-P	Coliform / E. Coli (CFU/MPN) / HPC / Fecal (CFU/MPN)	8015 DRO	8260B	8270C	Sample Comments
CL11-2512	Fuel	9/21/11	0000	1	1																X	X	X	
CL11-2513	↓	↓	↓	2	1																X	X	X	

TAT
- ☐ Routine
- ☐ Rush - Prelim
- ☐ Rush - Final

Prelim Due Date:

Final Due Date:

Total	200.7 / 6010B:	8RCRA 13PPM Al Sb As Ba Be B Cd Ca Cr Co Cu Fe Pb Mg Mn Mo Ni K Se Ag SiO2 Na Tl Sn V Zn
Circle Method(s) and Metal(s) to be analyzed	200.8 / 6020:	Sb As Ba Be Cd Cr Co Cu Pb Mn Mo Ni Se Ag Tl U Other: 245.1 / 7470A: Hg
Dissolved / TCLP	200.7 / 6010B:	8RCRA 13PPM Al Sb As Ba Be B Cd Ca Cr Co Cu Fe Pb Mg Mn Mo Ni K Se Ag SiO2 Na Tl Sn V Zn
Circle Method(s) and Metal(s) to be analyzed	200.8 / 6020:	Sb As Ba Be Cd Cr Co Cu Pb Mn Mo Ni Se Ag Tl U Other: 245.1 / 7470A: Hg

Relinquished by: (Signature)	Received by: (Signature)	Date/Time
1 Fed Ex	[signature]	9/22/11 1005
2		
3		

C.O.C. Serial # 13016

Container type :___________

XENCO Laboratories

Sample Receipt Checklist

Client Name: Southwest Research Inst.　　Date and Time Received: 9/22/11 1005

Work Order Number: 428081　　Checked by: Carlton Vicent

Checklist completed by: Carlton V　Date: 9/22/11　Logged In by: RtV　Date: 9/22

Matrix: Fuel　Courier Name: Client Xenco FedEx　Reviewed by: ________ Date: ______

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐	
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑	
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	Not Present ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐		
Samples in proper container/bottle?	Yes ☑	No ☐		
Sample containers intact?	Yes ☑	No ☐		
Sufficient sample volume for indicated test?	Yes ☑	No ☐		
All samples received within holding time?	Yes ☑	No ☐		
Samples received same day of collection?	Yes ☐	No ☑	Temp: 25.1	Wet Ice Present ☐
Where was the temperature reading taken at?	Sample ☑	Temp Blank ☐	Other:	
VOA Water – VOA vials have zero headspace?	Yes ☐	No ☐	N/A ☑	
Water – Microbiological bottles have ≤ 2.5 cm headspace?	Yes ☐	No ☐	N/A ☑	
Water – All sample pH's acceptable upon receipt?	Yes ☐	No ☐	N/A ☑	Checked by: _______

If No, list all samples and bottle types that are not acceptable in Additional Comments section. Also state any correction actions.

Sulfide Water – Bottles have zero headspace?	Yes ☐	No ☐	N/A ☑	(zero headspace ≤ than neck of bottle)
Dissolved Water Analytes – Field Filtered?	Yes ☐	No ☐	N/A ☑	
Are samples received deemed acceptable?	Yes ☑	No ☐	If No then complete section below	

PC Notified	Date: ________	Init: ________	PC Init: ________		
Client Notified	Date: ________	Init: ________	L/M ☐	Date: ______	L/M ☐ Date: ______
Contact Name: ____________		Action to take:	Analyze ☐	Cancel ☐	Hold ☐ Other:
Changes/Comments made on original COC?			Yes ☐	N/A ☐	Init: ______ Date: ______
Changes made in LIMS?			Yes ☐	N/A ☐	Init: ______ Date: ______

Additional Comments: ______________________________

CS-002-SRChecklist RV5

Appendix E-3

Neste Oil NExBTL HRJ

Table E-5. Neste Oil NExBTL HRJ Fit-For-Purpose Testing

Test	Method	Units	POSF-7066 SwRI CL10-1818 Neste Oil (NExBTL HRJ)	POSF7066 AFRL Results
Chemistry				
Hydrocarbon Types by Mass Spec	D2425			
Paraffins		mass%	96.6	>99
Monocycloparaffins		mass%	3.4	<1
Dicycloparaffins		mass%	0.0	
Tricycloparaffins		mass%	0.0	
TOTAL SATURATES		mass%	100.0	
Alkylbenzenes		mass%	0.0	<0.3
Indans/Tetralins		mass%	0.0	<0.3
Indenes		mass%	0.0	<0.3
Naphthalene		mass%	0.0	<0.3
Naphthalene, Alkyl		mass%	0.0	<0.3
Acenaphthenes		mass%	0.0	<0.3
Acenaphthylenes		mass%	0.0	<0.3
Tricyclic Aromatics		mass%	0.0	<0.3
TOTAL AROMATICS		mass%	0.0	100.0
Aromatic Content	D1319			
Aromatics		vol%	0.10	0.0
Olefins		vol%	0.20	
Saturates		vol%	99.70	
Hydrogen Content (NMR)	D3701	mass%	15.23	15.2 (method?)
Carbonyls, Alcohols, Esters, Phenols				
Alcohols	EPA 8015B		*See Report Below*	
Carbonyls, Esters	EPA 8260B			
Phenols	EPA 8270C			
Nitrogen Content	D4629	mg/kg	1.0	
Elemental Analysis	UOP 389			Metals by ICP-MS
Fe		ppm	0.06	<5-ppb
Ni		ppm	<0.02	<5-ppb
V		ppm	<0.02	12.0-ppb
Pb		ppm	<0.02	<5-ppb
Cu		ppm	<0.02	<5-ppb
Na		ppm	<0.02	<5-ppb
Mo		ppm	<0.02	<5-ppb
Mn		ppm	<0.02	<5-ppb
Cr		ppm	<0.02	<5-ppb

Table E-5. Neste Oil NExBTL HRJ Fit-For-Purpose Testing

Test	Method	Units	POSF-7066 SwRI CL10-1818 Neste Oil (NExBTL HRJ)	POSF7066 AFRL Results
Mg		ppm	<0.02	6.0-ppb
Sn		ppm	<0.02	<5-ppb
Ca		ppm	0.18	<5-ppb
Al		ppm	<0.02	285.0-ppb
Zn		ppm	<0.02	<5-ppb
Co		ppm	<0.02	<5-ppb
K		ppm	0.02	<5-ppb
Li		ppm	<0.02	
P		ppm	<0.02	<500-ppb
Pd		ppm	<0.02	
Pt		ppm	<0.02	
Sr		ppm	<0.02	<5-ppb
Ti		ppm	<0.02	<5-ppb
Bulk Physical and Performance Properties				
Distillation	D86			
IBP		°C	142.8	145.0
5%		°C	173.4	
10%		°C	193.1	189.0
15%		°C	209.5	
20%		°C	222.6	218.0
30%		°C	245.7	
40%		°C	258.5	
50%		°C	265.1	265.0
60%		°C	269.8	
70%		°C	273.5	
80%		°C	277.7	
90%		°C	283.0	284.0
95%		°C	287.5	
FBP		°C	292.1	294.0
Residue		%	1.5	≤1.5
Loss		%	0.7	≤1.0
T50-T10		°C	72.0	
T90-T10		°C	89.9	95.0
Vapor pressure (Absolute)	D6378			
0 °C		psi	0.13	
10 °C		psi	0.20	
20 °C		psi	0.24	
30 °C		psi	0.30	
40 °C		psi	0.38	
50 °C		psi	0.47	

Table E-5. Neste Oil NExBTL HRJ Fit-For-Purpose Testing

Test	Method	Units	POSF-7066 SwRI CL10-1818 Neste Oil (NExBTL HRJ)	POSF7066 AFRL Results
60 °C		psi	0.61	
70 °C		psi	0.79	
80 °C		psi	1.03	
90 °C		psi	1.33	
100 °C		psi	1.71	
110 °C		psi	2.19	
120 °C		psi	2.83	
JFTOT Breakpoint	D3241BP	°C		
Test Temperature		°C	>325	
ASTM Code		rating	2	
Maximum Pressure Drop		mm Hg	1.0	
Lubricity (BOCLE)	D5001	mm	0.92	0.80
Lubricity (BOCLE) vs. CI/LI Concentration	D5001			
0 mg/L		mm	0.89	
5 mg/L		mm	0.79	
10 mg/L		mm	0.60	
15 mg/L		mm	0.55	
20 mg/L		mm	0.50	
Lubricity (HFRR)	D6079	mm	0.57	
Lubricity (HFRR) vs. CI/LI Concentration	D6079			
0 mg/L		mm	0.61	
5 mg/L		mm	0.58	
10 mg/L		mm	0.58	
15 mg/L		mm	0.59	
20 mg/L		mm	0.60	
Kinematic Viscosity	D445			
-39.90°C		cSt	28.71	28.9
-19.9°C		cSt	10.56	10.90
25°C		cSt	2.84	
40°C		cSt	2.13	2.10
Specific Heat Capacity	E2716			
-25°C		kJ/kg.K	2.183	
0°C		kJ/kg.K	2.252	
25°C		kJ/kg.K	2.298	
50°C		kJ/kg.K	2.367	
100°C		kJ/kg.K	2.547	
150°C		kJ/kg.K	2.773	
Density	D4052			
5°C		g/cm^3	0.7780	
15°C		g/cm^3	0.7709	0.7720

Table E-5. Neste Oil NExBTL HRJ Fit-For-Purpose Testing

Test	Method	Units	POSF-7066 SwRI CL10-1818 Neste Oil (NExBTL HRJ)	POSF7066 AFRL Results
40°C		g/cm^3	0.7532	0.7530
60°C		g/cm^3	0.7392	
80°C		g/cm^3	0.7248	
Surface tension	D1331A			
-7.8°C		mN/m	26.8	
22°C		mN/m	25.2	
42°C		mN/m	23.1	
Speed of Sound (30°C)		m/s	1275	
Isentropic Bulk Modulus (30°C)		psig	179,293	
Thermal Conductivity	SwRI			
0°C		W/m.K	0.095	
25°C		W/m.K	0.093	
50°C		W/m.K	0.091	
Water Content	D6304	ppm	18	20.0
Water Content	D6304			
0°C		ppm	46	
30°C		ppm	61	
40°C		ppm	86	
50°C		ppm	155	
Flash Point – Tag Closed	D56	°C	48.0	
Freeze Point (manual)	D2386	°C	-52.0	
Freeze Point	D5972	°C	-49.8	-55.0
Electrical Properties				
Dielectric Constant (10kHz)	SwRI			
-35.1°C		---	2.100	
-20.8°C		---	2.083	
0.2°C		---	2.057	
30.8°C		---	2.022	
50.6°C		---	2.000	
80.0°C		---	1.968	
Electrical Conductivity	D2624	pS/m	3 (@17.2°C)	0.0
Electrical Conductivity vs. SDA Concentration	D2624			
0 mg/L		pS/m	0	
1 mg/L		pS/m	196	
2 mg/L		pS/m	389	
3 mg/L		pS/m	528	
4 mg/L		pS/m	684	
Electrical Conductivity vs. Temperature	D2624			
-40		pS/m	--	
-30		pS/m	0.0	

Table E-5. Neste Oil NExBTL HRJ Fit-For-Purpose Testing

Test	Method	Units	POSF-7066 SwRI CL10-1818 Neste Oil (NExBTL HRJ)	POSF7066 AFRL Results
-20		pS/m	0.0	
-10		pS/m	0.0	
0		pS/m	0.0	
10		pS/m	0.0	
20		pS/m	0.0	
30		pS/m	0.0	
40		pS/m	0.0	
50		pS/m	10.0	
60		pS/m	63.0	
70		pS/m	214.0	
80		pS/m	582.0	
Ground Handling Properties and Safety				
MSEP	D3948	rating	95	
Storage Stability – Peroxides @65°C	D3703			
0 week		mg/kg	2.56	
1 week		mg/kg	0.640	
2 week		mg/kg	0.560	
3 week		mg/kg	2.240	
6 week		mg/kg	2.560	
Storage Stability – Potential Gums	D5304			
16 hours @ 100°C		mg/100mL	94.0	
16 hours @ 100°C		mg/100mL	11.0	
16 hours @ 100°C		mg/100mL	11.2	
Upper Explosion Limit (UEL), @100°C	E681	%	3.9 ± 0.1	
Lower Explosion Limit (LEL), @100°C	E681	%	0.4 ± 0.1	
Autoignition temperature	E659			
Hot Flame Autoignition Temperature		°C	199	
Hot Flame Lag Time		seconds	194	
Cool Flame Autoignition Temperature		°C	*N/A*	
Cool Flame Lag Time		seconds	*N/A*	
Barometric Pressure		mm Hg	738.8	
Reaction Threshold Temperature		°C	181.0	
Hot surface ignition	FTM 791-6053	°F	1225	
Compatibility				
Fuel/Additive Compatibility (4x treat rate)	D4054B			
FSII		effect	No Separation Observed	
SDA		effect	No Separation Observed	
CI/LI		effect	No Separation Observed	
MDA		effect	No Separation Observed	
AO		effect	No Separation Observed	

Table E-5. Neste Oil NExBTL HRJ Fit-For-Purpose Testing

Test	Method	Units	POSF-7066 SwRI CL10-1818 Neste Oil (NExBTL HRJ)	POSF7066 AFRL Results
+100		effect	No Separation Observed	
Additive Cocktail (MDA, AO, SDA, CI/LI, FSII,+100)		effect	No Separation Observed	
Elastomer Compatibility (O-Ring Tests)	SwRI		*See Figure E-32, Figure E-33, Figure E-34*	
Miscellaneous				
Ignition Quality Test (IQT)	D6890			
Ignition Delay, ID		ms	2.962	
Derived Cetane Number, DCN			69.3	

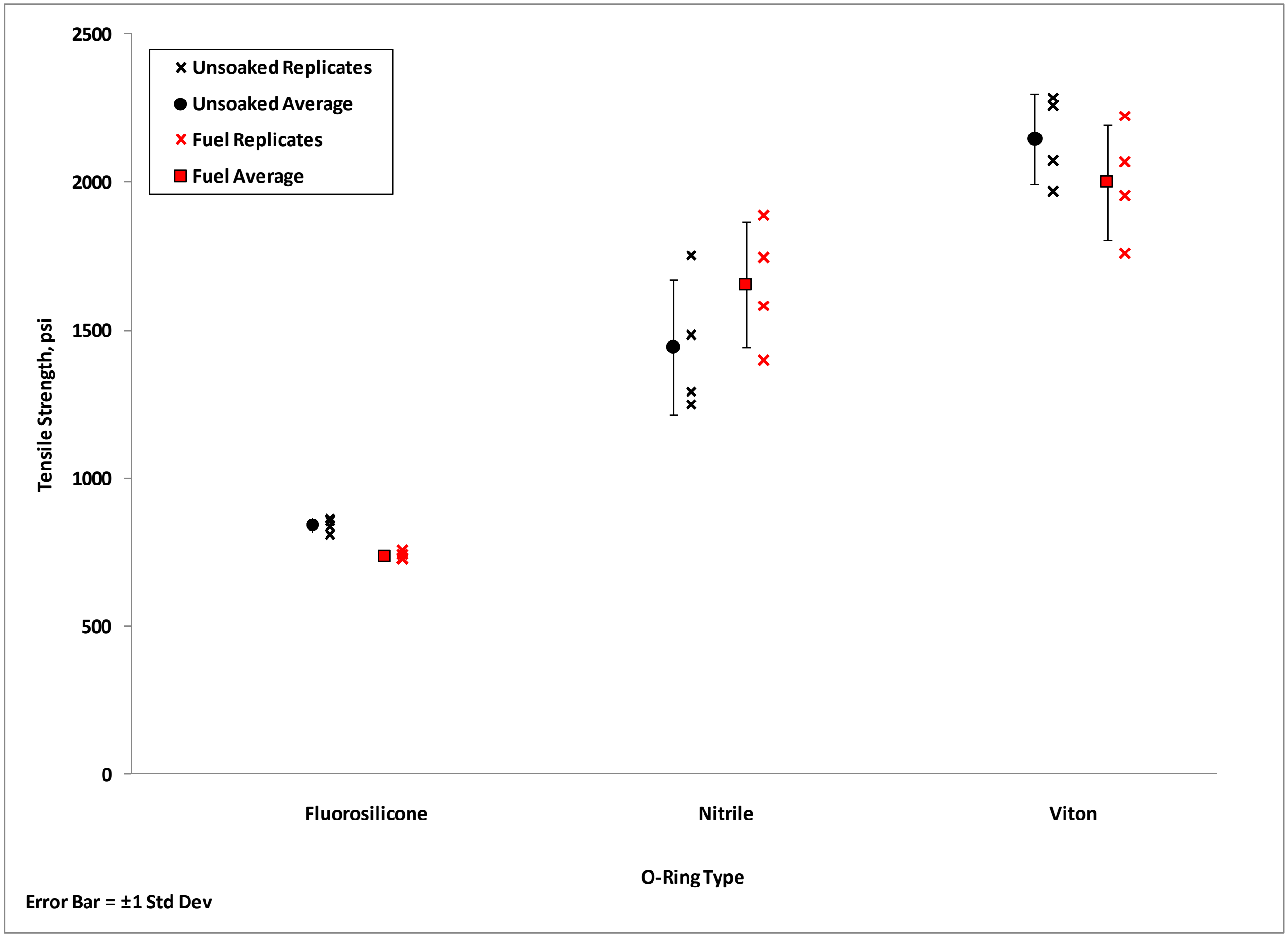

Figure E-32. Neste NExBTL HRJ (CL10-1818) O-Ring Data – Tensile Strength

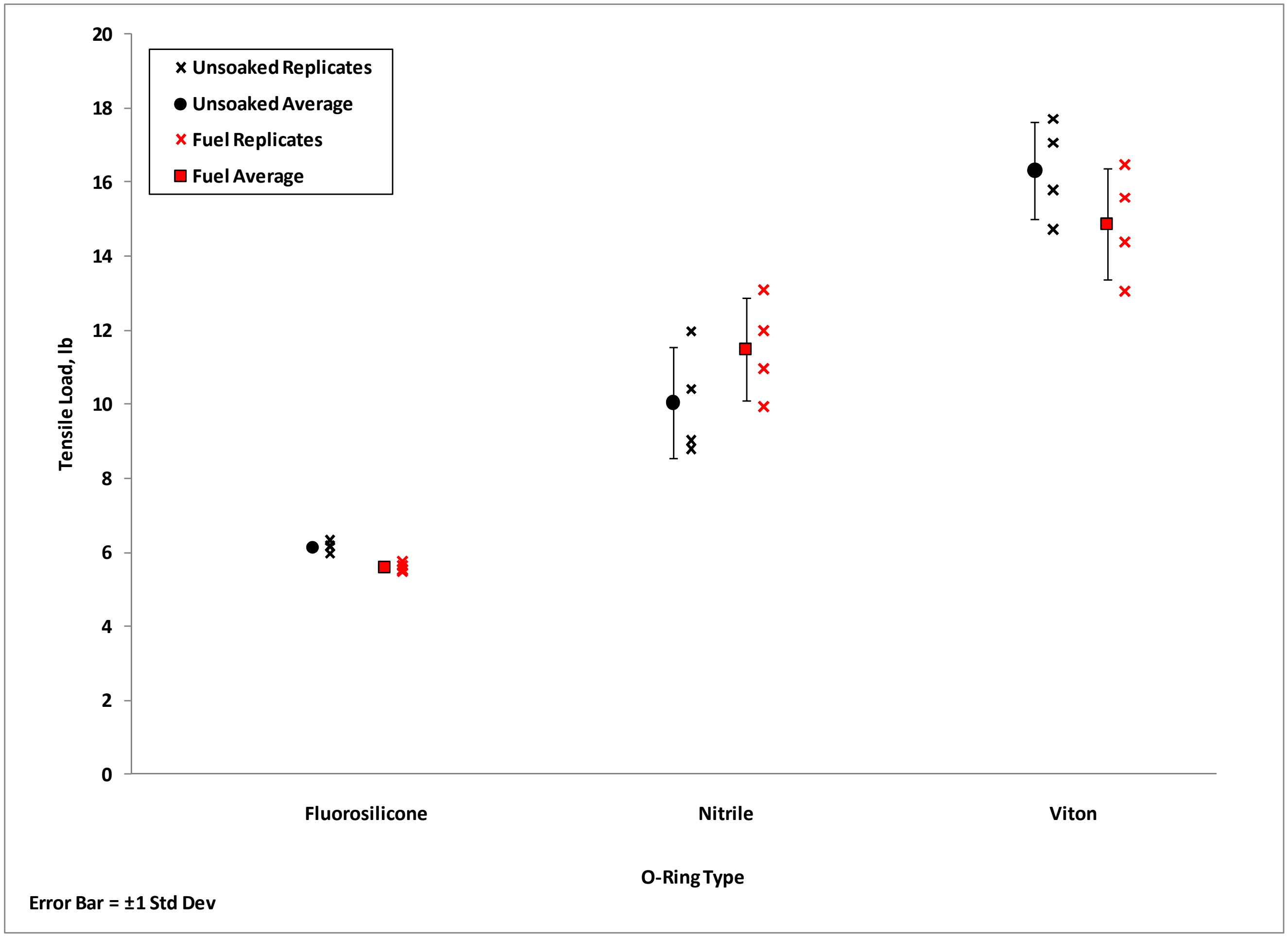

Figure E-33. Neste NExBTL HRJ (CL10-1818) O-Ring Data - Tensile Load

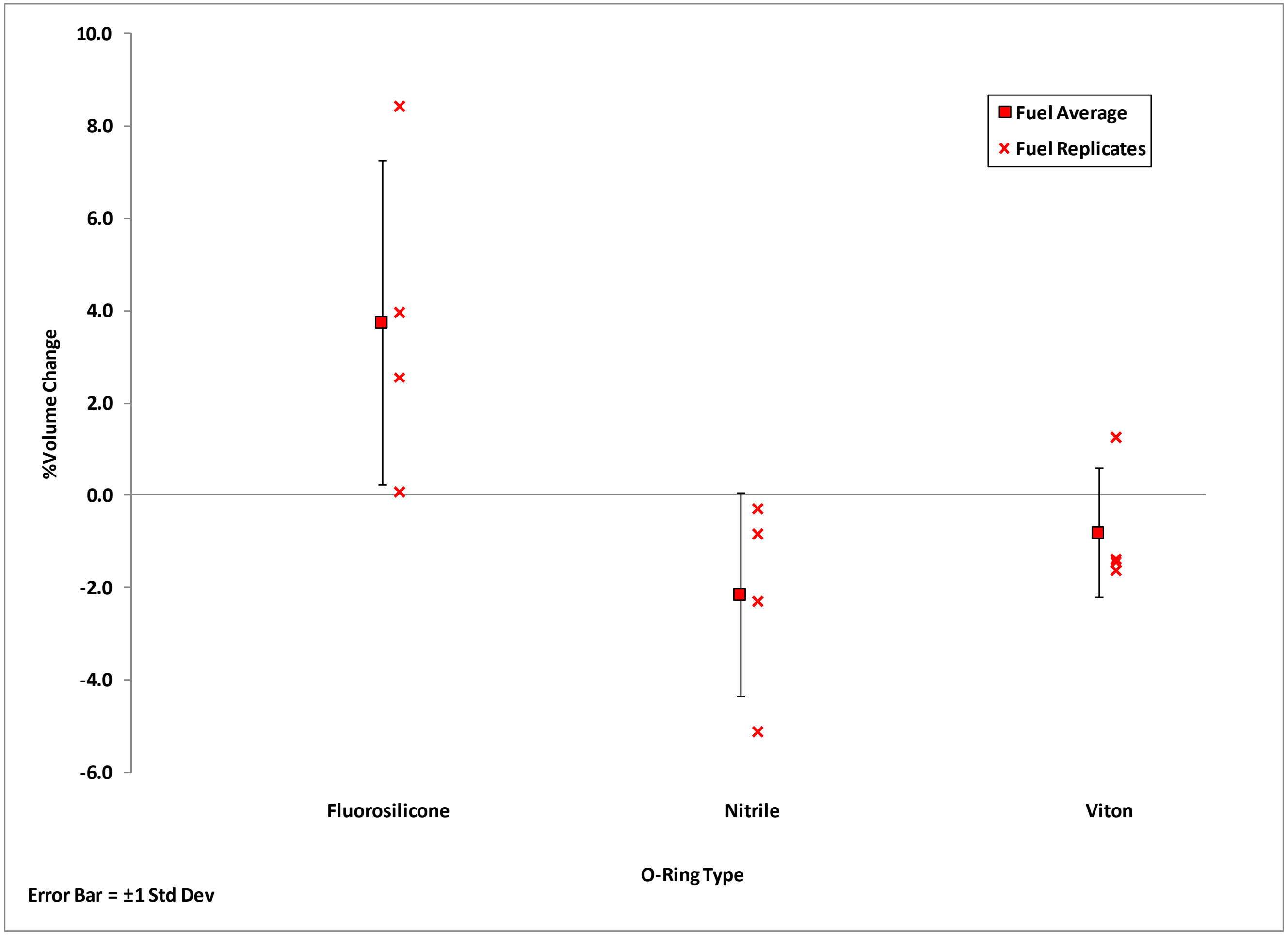

Figure E-34. Neste NExBTL HRJ (CL10-1818) O-Ring Data - Volume Change

XENCO Laboratories
Trans West Analytical Services

3725 E. Atlanta Avenue, Phoenix, AZ 85040 | 602-437-0330 | www.xenco.com

April 07, 2011

Scott Hutzler
Southwest Research Institute
9503 West Commerce
San Antonio, TX 78227-1301

RE: 1.08.07.13.16246.05.001

Work Order No.: 00402000

Dear Scott,

XENCO Laboratories, Inc. received 1 sample on 12/29/10. The results of the analyses are presented in the following report.

The Case Narrative of this report addresses any Quality Control and/or Quality Assurance issues associated with this Work Order.

Analyses were performed according to our laboratory's NELAP-approved quality assurance program. The test results meet requirements of the current NELAP standards, where applicable, and except as noted in the laboratory case narrative provided. For a specific list of NELAP-accredited analytes, refer to the certifications section at www.xenco.com. All results are intended to be considered in their entirety and XENCO Laboratories is not responsible for use of less than the complete report. Results apply only to the items submitted to the laboratory for analysis and individual items (samples) analyzed, as listed in the report.

If you have any questions regarding these test results, please feel free to call us at: (602) 437-0330.

Sincerely,

Skip Harden
Project Manager

ADHS License No. AZ0757/AZ0758/AZM757

XENCO Laboratories
Trans West Analytical Services

Client: Southwest Research Institute
Work Order: 00402000
Project Name:
Project Number: 1.08.07.13.16246.05.001

Case Narrative

The samples were received intact at a temperature of 22.7 degrees C. A valid chain-of-custody was not received.

Results are reported on a wet weight basis unless dry-correction is denoted in the units field on the analytical report ("mg/kg-dry").

All method blanks, laboratory spikes, and/or matrix spikes met quality control objectives for the parameters associated with this Work Order except as detailed below or on the Data Qualifier page of this report. Data Qualifiers used in this report are in accordance with ADEQ Arizona Data Qualifiers, Revision 3.0 9/20/2007.

Data qualifiers ("flags") contained within this analytical report have been issued to explain a quality control deficiency, and do not affect the quality (validity) of the data unless noted otherwise in the case narrative.

N1:Analytical Comments for Method SW8270C, LCS/LCSD, Batch 7151: MS/MSD was not extracted due to the nature of the sample matrix. If extracted, the spiked MS/MSD sample would require such a dilution that spike compounds would not be detected. The benzoic acid recovery in the LCS was low. The 2,4-dinitrophenol recovery in the LCS was low. No historical control limits have been generated yet for LCS/LCSD recoveries.

N1:Analytical Comments for Method SW8220B, LCS/LCSD, Batch 7169: MS/MSD was not extracted due to the nature of the sample matrix. If extracted, the spiked MS/MSD sample would require such a dilution that spike compounds would not be detected.

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CLIENT:	Southwest Research Institute
Project Name:	
Project Number:	1.08.07.13.16246.05.001
Work Order:	00402000
Date Received:	29-Dec-10

Case Narrative
Data Qualifiers

One or more of the following data qualifiers may be associated with your analytical and/or quality control data.

D1 Sample required dilution due to matrix.

N1 See case narrative.

S8 The analysis of the sample required a dilution such that the surrogate recovery calculation does not provide any useful information. The associated blank spike recovery was acceptable.

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CLIENT: Southwest Research Institute
Project Name:
Project Number: 1.08.07.13.16246.05.001
Work Order: 00402000

Work Order Sample Summary

Client Sample ID	Lab Sample ID	Test Code	Collection Date	Date Received
1	00402000-01A	SW8260B	12/28/10 12:00 AM	12/29/10 09:55 AM
		SW8260TIC	12/28/10 12:00 AM	12/29/10 09:55 AM
		SW8270C	12/28/10 12:00 AM	12/29/10 09:55 AM
		SW8270TIC	12/28/10 12:00 AM	12/29/10 09:55 AM

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License No. AZ0757/AZM757

CLIENT: Southwest Research Institute
Work Order: 00402000
Lab ID: 00402000-01
Project Name:
Project Number: 1.08.07.13.16246.05.001

Client Sample ID: 1
Collection Date: 12/28/2010
Matrix: Liquid

TEST METHOD: SW8270C PREP METHOD: SW3580A Test Performed By: AZ0757

Analyte	Result	PQL	Qual	Units	DF	Date Prepared	Date Analyzed	Analyst	Batch ID
Acenaphthene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Acenaphthylene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Anthracene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Azobenzene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Benz[a]anthracene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Benzo[a]pyrene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Benzo[b]fluoranthene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Benzo[g,h,i]perylene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Benzo[k]fluoranthene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Benzoic acid	<75000	75000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Benzyl alcohol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Bis(2-chloroethoxy)methane	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Bis(2-chloroethyl)ether	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Bis(2-chloroisopropyl)ether	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Bis(2-ethylhexyl)phthalate	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
4-Bromophenyl phenyl ether	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Butyl benzyl phthalate	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
4-Chloro-3-methylphenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
4-Chloroaniline	<10000	10000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2-Chloronaphthalene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2-Chlorophenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
4-Chlorophenyl phenyl ether	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Chrysene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Di-n-butyl phthalate	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Di-n-octyl phthalate	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Dibenz[a,h]anthracene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Dibenzofuran	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
1,2-Dichlorobenzene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
1,3-Dichlorobenzene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
1,4-Dichlorobenzene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
3,3´-Dichlorobenzidine	<25000	25000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2,4-Dichlorophenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Diethyl phthalate	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Dimethyl phthalate	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2,4-Dimethylphenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
4,6-Dinitro-2-methylphenol	<10000	10000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2,4-Dinitrophenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2,4-Dinitrotoluene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2,6-Dinitrotoluene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151

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CLIENT: Southwest Research Institute
Work Order: 00402000
Lab ID: 00402000-01
Project Name:
Project Number: 1.08.07.13.16246.05.001

Client Sample ID: 1
Collection Date: 12/28/2010
Matrix: Liquid

Analyte	Result	PQL	Qual	Units	DF	Date Prepared	Date Analyzed	Analyst	Batch ID
Fluoranthene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Fluorene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Hexachlorobenzene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Hexachlorobutadiene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Hexachlorocyclopentadiene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Hexachloroethane	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Indeno[1,2,3-cd]pyrene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Isophorone	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2-Methylnaphthalene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2-Methylphenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
4-Methylphenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
N-Nitrosodi-n-propylamine	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
N-Nitrosodiphenylamine	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Naphthalene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Nitrobenzene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2-Nitrophenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
4-Nitrophenol	<15000	15000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Pentachlorophenol	<10000	10000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Phenanthrene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Phenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Pyrene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
1,2,4-Trichlorobenzene	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2,4,6-Trichlorophenol	<5000	5000	D1	mg/Kg	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2-Chlorophenol-d4(Surrogate)	0	52-148	S8	%REC	50	1/4/11 16:00	1/11/11 20:36	JH	7151
1,2-Dichlorobenzene-d4(Surrogate)	0	54-148	S8	%REC	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2-Fluorobiphenyl(Surrogate)	0	54-142	S8	%REC	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2-Fluorophenol(Surrogate)	0	54-144	S8	%REC	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Nitrobenzene-d5(Surrogate)	0	50-151	S8	%REC	50	1/4/11 16:00	1/11/11 20:36	JH	7151
Phenol-d6(Surrogate)	0	51-149	S8	%REC	50	1/4/11 16:00	1/11/11 20:36	JH	7151
4-Terphenyl-d14(Surrogate)	0	58-144	S8	%REC	50	1/4/11 16:00	1/11/11 20:36	JH	7151
2,4,6-Tribromophenol(Surrogate)	0	34-139	S8	%REC	50	1/4/11 16:00	1/11/11 20:36	JH	7151

TEST METHOD: SW8260B PREP METHOD: SW5035A Test Performed By: AZ0757

Analyte	Result	PQL	Qual	Units	DF	Date Prepared	Date Analyzed	Analyst	Batch ID
Acetone	<1500	1500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Benzene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Bromobenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Bromochloromethane	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Bromodichloromethane	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Bromoform	<100	100	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Bromomethane	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
2-Butanone	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169

2 of 4

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CLIENT: Southwest Research Institute
Work Order: 00402000
Lab ID: 00402000-01
Project Name:
Project Number: 1.08.07.13.16246.05.001

Client Sample ID: 1
Collection Date: 12/28/2010
Matrix: Liquid

Analyte	Result	PQL	Qual	Units	DF	Date Prepared	Date Analyzed	Analyst	Batch ID
n-Butylbenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
sec-Butylbenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
tert-Butylbenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Carbon disulfide	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Carbon tetrachloride	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Chlorobenzene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Dibromochloromethane	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Chloroethane	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Chloroform	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Chloromethane	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
2-Chlorotoluene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
4-Chlorotoluene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2-Dibromo-3-chloropropane	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2-Dibromoethane	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Dibromomethane	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2-Dichlorobenzene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,3-Dichlorobenzene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,4-Dichlorobenzene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Dichlorodifluoromethane	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,1-Dichloroethane	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2-Dichloroethane	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,1-Dichloroethene	<100	100	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
cis-1,2-Dichloroethene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
trans-1,2-Dichloroethene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2-Dichloropropane	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,3-Dichloropropane	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
2,2-Dichloropropane	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,1-Dichloropropene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
cis-1,3-Dichloropropene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
trans-1,3-Dichloropropene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Ethylbenzene	<100	100	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Hexachlorobutadiene	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
2-Hexanone	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Iodomethane	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Isopropylbenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
4-Isopropyltoluene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Methylene chloride	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
4-Methyl-2-pentanone	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Methyl tert-butyl ether	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Naphthalene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
n-Propylbenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169

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License No. AZ0757/AZM757

CLIENT: Southwest Research Institute
Work Order: 00402000
Lab ID: 00402000-01
Project Name:
Project Number: 1.08.07.13.16246.05.001

Client Sample ID: 1
Collection Date: 12/28/2010
Matrix: Liquid

Analyte	Result	PQL	Qual	Units	DF	Date Prepared	Date Analyzed	Analyst	Batch ID
Styrene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,1,1,2-Tetrachloroethane	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,1,2,2-Tetrachloroethane	<100	100	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Tetrachloroethene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Toluene	<100	100	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2,3-Trichlorobenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2,4-Trichlorobenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,1,1-Trichloroethane	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,1,2-Trichloroethane	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Trichloroethene	<50	50	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Trichlorofluoromethane	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2,3-Trichloropropane	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2,4-Trimethylbenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,3,5-Trimethylbenzene	<250	250	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Vinyl acetate	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Vinyl chloride	<500	500	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Xylenes, Total	<150	150	D1	mg/Kg	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
4-Bromofluorobenzene(Surrogate)	0	62-123	S8	%REC	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
1,2-Dichloroethane-d4(Surrogate)	0	54-133	S8	%REC	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Dibromofluoromethane(Surrogate)	0	52-140	S8	%REC	1000	1/11/11 8:10	1/11/11 15:21	BK	7169
Toluene-d8(Surrogate)	0	63-126	S8	%REC	1000	1/11/11 8:10	1/11/11 15:21	BK	7169

TENTATIVELY IDENTIFIED COMPOUNDS
EPA METHOD 8260B

CLIENT:	**Southwest Research Institute**	**Client Sample ID:**	1
Work Order:	402000	**Collection Date:**	12/28/2010
LAB ID:	402000-01A	**Matrix:**	Jet Fuel
Project Name:		**Date Prepared:**	1/11/2011
Project Number:	1.08.07.13.16246.05.001	**Date Analyzed:**	1/11/2011

No.	CAS #	Compound Name	Amount (mg/Kg)
1.	111-84-2	Nonane	5500
2.	2847-72-5	4-methyl-decane	6500
3.	5911-04-6	3-methyl-nonane	4050
4.	2216-33-3	3-methyl-octane	5500
5.	592-27-8	2-methyl-heptane	6500
6.	13151-35-4	5-methyl-decane	9000
7.	15869-89-3	2,5-dimethyl-octane	3100
8.	17318-70-6	4,6-dimethyl-decane	4650
9.			
10.			
11.			
12.			
13.			

Values reported for Tentatively Identified Compounds are estimated.

TENTATIVELY IDENTIFIED COMPOUNDS
EPA METHOD 8270C

CLIENT: Southwest Research Institute
Work Order: 402000
LAB ID: 402000-01A
Project Name:
Project Number: 1.08.07.13.16246.05.001

Client Sample ID: 1
Collection Date: 12/28/2010
Matrix: Jet Fuel
Date Prepared: 1/4/2011
Date Analyzed: 1/11/2011
Dilution Factor: 50
Analyst: JH

No.	CAS #	Compound Name	Amount (mg/Kg)
1.	592-27-8	2-methyl-heptane	6300
2.	17301-94-9	4-methyl-nonane	7900
3.	13287-23-5	8-methyl-heptadecane	6300
4.	54833-23-7	10-methyl-eicosane	8600
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			

Values reported for Tentatively Identified Compounds are estimated.

XENCO Laboratories
Trans West Analytical Services

QC SUMMARY REPORT

Client - Southwest Research Institute
Work Order - 00402000
Project -

MB, LCS, LCSD REPORT

SW8260B

Batch ID - 7169 Prep Date - 1/11/11 7:45

Units - mg/Kg

Analyte	MB Result	LCS Result	LCSD Result	Spike Value	LCS REC	LCSD REC	Low - High % Limit	% RPD	RPD Limit	MB Qual	LCS Qual	LCSD Qual	Date Analyzed
Acetone	<1.5	1.49	1.49	2.00	75%	75%	52 - 140	<1%	23		N1	N1	01/11/11
Benzene	<0.050	1.01	1.01	1.00	101%	101%	70 - 130	<1%	20		N1	N1	01/11/11
Bromobenzene	<0.25	1.03	1.04	1.00	103%	104%	70 - 130	1%	20		N1	N1	01/11/11
Bromochloromethane	<0.050	0.953	1.02	1.00	95%	102%	70 - 130	7%	20		N1	N1	01/11/11
Bromodichloromethane	<0.050	1.02	1.06	1.00	102%	106%	70 - 130	4%	20		N1	N1	01/11/11
Bromoform	<0.10	0.924	0.981	1.00	92%	98%	64 - 120	6%	20		N1	N1	01/11/11
Bromomethane	<0.50	1.63	1.59	2.00	81%	80%	21 - 168	2%	56		N1	N1	01/11/11
2-Butanone	<0.50	1.64	1.79	2.00	82%	90%	70 - 133	9%	23		N1	N1	01/11/11
n-Butylbenzene	<0.25	1.09	1.08	1.00	109%	108%	70 - 130	1%	20		N1	N1	01/11/11
sec-Butylbenzene	<0.25	1.09	1.08	1.00	109%	108%	70 - 130	1%	20		N1	N1	01/11/11
tert-Butylbenzene	<0.25	1.10	1.09	1.00	110%	109%	70 - 130	1%	20		N1	N1	01/11/11
Carbon disulfide	<0.50	1.51	1.51	2.00	76%	76%	43 - 164	<1%	38		N1	N1	01/11/11
Carbon tetrachloride	<0.050	1.12	1.11	1.00	112%	111%	70 - 130	1%	20		N1	N1	01/11/11
Chlorobenzene	<0.050	1.03	1.03	1.00	103%	103%	70 - 130	<1%	20		N1	N1	01/11/11
Dibromochloromethane	<0.050	1.06	1.07	1.00	106%	107%	70 - 130	1%	20		N1	N1	01/11/11
Chloroethane	<0.50	1.68	1.58	2.00	84%	79%	35 - 156	6%	48		N1	N1	01/11/11
Chloroform	<0.050	1.03	1.08	1.00	103%	108%	70 - 130	5%	20		N1	N1	01/11/11
Chloromethane	<0.50	1.15	1.22	2.00	58%	61%	36 - 153	6%	41		N1	N1	01/11/11
2-Chlorotoluene	<0.25	1.11	1.09	1.00	111%	109%	70 - 130	2%	20		N1	N1	01/11/11
4-Chlorotoluene	<0.25	1.09	1.11	1.00	109%	111%	70 - 130	2%	20		N1	N1	01/11/11
1,2-Dibromo-3-chloropropane	<0.50	0.901	0.952	1.00	90%	95%	64 - 114	6%	20		N1	N1	01/11/11
1,2-Dibromoethane	<0.50	1.00	1.07	1.00	100%	107%	70 - 130	7%	20		N1	N1	01/11/11
Dibromomethane	<0.25	0.939	0.992	1.00	94%	99%	70 - 130	5%	20		N1	N1	01/11/11
1,2-Dichlorobenzene	<0.050	1.03	1.05	1.00	103%	105%	70 - 130	2%	20		N1	N1	01/11/11
1,3-Dichlorobenzene	<0.050	1.02	1.05	1.00	102%	105%	70 - 130	3%	20		N1	N1	01/11/11
1,4-Dichlorobenzene	<0.050	1.02	1.00	1.00	102%	100%	70 - 130	2%	20		N1	N1	01/11/11
Dichlorodifluoromethane	<0.50	1.28	1.30	2.00	64%	65%	12 - 169	2%	49		N1	N1	01/11/11
1,1-Dichloroethane	<0.050	1.08	1.12	1.00	108%	112%	70 - 130	4%	20		N1	N1	01/11/11
1,2-Dichloroethane	<0.050	1.00	1.03	1.00	100%	103%	70 - 130	3%	20		N1	N1	01/11/11
1,1-Dichloroethene	<0.10	0.824	0.850	1.00	82%	85%	59 - 126	3%	21		N1	N1	01/11/11
cis-1,2-Dichloroethene	<0.050	1.05	1.09	1.00	105%	109%	70 - 130	4%	20		N1	N1	01/11/11
trans-1,2-Dichloroethene	<0.050	1.06	1.07	1.00	106%	107%	70 - 130	1%	20		N1	N1	01/11/11
1,2-Dichloropropane	<0.050	1.01	1.03	1.00	101%	103%	70 - 130	2%	20		N1	N1	01/11/11
1,3-Dichloropropane	<0.25	0.996	1.05	1.00	100%	105%	70 - 130	5%	20		N1	N1	01/11/11
2,2-Dichloropropane	<0.25	1.05	1.03	1.00	105%	103%	64 - 123	2%	20		N1	N1	01/11/11
1,1-Dichloropropene	<0.25	1.06	1.07	1.00	106%	107%	70 - 130	1%	20		N1	N1	01/11/11
cis-1,3-Dichloropropene	<0.050	0.995	1.02	1.00	100%	102%	70 - 130	2%	20		N1	N1	01/11/11
trans-1,3-Dichloropropene	<0.050	1.01	1.06	1.00	101%	106%	70 - 130	5%	20		N1	N1	01/11/11
Ethylbenzene	<0.10	1.04	1.06	1.00	104%	106%	70 - 130	2%	20		N1	N1	01/11/11
Hexachlorobutadiene	<0.50	1.05	1.01	1.00	105%	101%	70 - 130	4%	20		N1	N1	01/11/11
2-Hexanone	<0.50	1.68	1.82	2.00	84%	91%	70 - 130	8%	20		N1	N1	01/11/11
Iodomethane	<0.50	1.50	1.69	2.00	75%	85%	53 - 157	12%	31		N1	N1	01/11/11
Isopropylbenzene	<0.25	1.03	1.04	1.00	103%	104%	70 - 130	1%	20		N1	N1	01/11/11
4-Isopropyltoluene	<0.25	1.11	1.09	1.00	111%	109%	70 - 130	2%	20		N1	N1	01/11/11
Methylene chloride	<0.50	1.06	1.08	1.00	106%	108%	70 - 130	2%	20		N1	N1	01/11/11
4-Methyl-2-pentanone	<0.50	1.65	1.86	2.00	83%	93%	70 - 130	12%	20		N1	N1	01/11/11
Methyl tert-butyl ether	<0.25	1.88	1.98	2.00	94%	99%	70 - 130	5%	20		N1	N1	01/11/11
Naphthalene	<0.25	0.967	1.00	1.00	97%	100%	70 - 130	3%	20		N1	N1	01/11/11

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QC SUMMARY REPORT

Client - Southwest Research Institute

Work Order - 00402000

Project -

MB, LCS, LCSD REPORT

Analyte	MB Result	LCS Result	LCSD Result	Spike Value	LCS REC	LCSD REC	Low - High % Limit	% RPD	RPD Limit	MB Qual	LCS Qual	LCSD Qual	Date Analyzed
n-Propylbenzene	<0.25	1.12	1.10	1.00	112%	110%	70 - 130	2%	20		N1	N1	01/11/11
Styrene	<0.25	1.01	1.03	1.00	101%	103%	70 - 130	2%	20		N1	N1	01/11/11
1,1,1,2-Tetrachloroethane	<0.25	1.00	1.00	1.00	100%	100%	70 - 130	<1%	20		N1	N1	01/11/11
1,1,2,2-Tetrachloroethane	<0.10	0.849	0.885	1.00	85%	89%	70 - 130	4%	20		N1	N1	01/11/11
Tetrachloroethene	<0.050	1.03	1.02	1.00	103%	102%	70 - 130	1%	20		N1	N1	01/11/11
Toluene	<0.10	1.03	1.03	1.00	103%	103%	70 - 130	<1%	20		N1	N1	01/11/11
1,2,3-Trichlorobenzene	<0.25	0.969	1.00	1.00	97%	100%	70 - 130	3%	20		N1	N1	01/11/11
1,2,4-Trichlorobenzene	<0.25	0.987	1.01	1.00	99%	101%	70 - 130	2%	20		N1	N1	01/11/11
1,1,1-Trichloroethane	<0.050	1.11	1.11	1.00	111%	111%	70 - 130	<1%	20		N1	N1	01/11/11
1,1,2-Trichloroethane	<0.050	0.975	1.05	1.00	98%	105%	70 - 130	7%	20		N1	N1	01/11/11
Trichloroethene	<0.050	1.07	1.08	1.00	107%	108%	70 - 130	1%	20		N1	N1	01/11/11
Trichlorofluoromethane	<0.50	1.66	1.72	2.00	83%	86%	54 - 136	4%	34		N1	N1	01/11/11
1,2,3-Trichloropropane	<0.25	0.987	1.04	1.00	99%	104%	70 - 130	5%	20		N1	N1	01/11/11
1,2,4-Trimethylbenzene	<0.25	1.10	1.08	1.00	110%	108%	70 - 130	2%	20		N1	N1	01/11/11
1,3,5-Trimethylbenzene	<0.25	1.13	1.09	1.00	113%	109%	70 - 130	4%	20		N1	N1	01/11/11
Vinyl acetate	<0.50	1.18	1.09	2.00	59%	55%	22 - 183	8%	20		N1	N1	01/11/11
Vinyl chloride	<0.50	1.42	1.47	2.00	71%	74%	38 - 154	3%	20		N1	N1	01/11/11
Xylenes, Total	<0.15	3.12	3.16	3.00	104%	105%	70 - 130	1%	20		N1	N1	01/11/11
4-Bromofluorobenzene	94%	2.20	2.25	2.50	88%	90%	62 - 123						01/11/11
1,2-Dichloroethane-d4	93%	2.18	2.26	2.50	87%	90%	54 - 133						01/11/11
Dibromofluoromethane	98%	2.37	2.46	2.50	95%	98%	52 - 140						01/11/11
Toluene-d8	91%	2.17	2.17	2.50	87%	87%	63 - 126						01/11/11

SW8270C

Batch ID - 7151 Prep Date - 1/4/11 16:00 ***Units - mg/Kg***

Analyte	MB Result	LCS Result	LCSD Result	Spike Value	LCS REC	LCSD REC	Low - High % Limit	% RPD	RPD Limit	MB Qual	LCS Qual	LCSD Qual	Date Analyzed
Acenaphthene	<100	196	201	200	98%	101%	70 - 130	3%	20		N1	N1	01/07/11
Acenaphthylene	<100	193	192	200	97%	96%	70 - 130	1%	20		N1	N1	01/07/11
Anthracene	<100	182	186	200	91%	93%	70 - 130	2%	20		N1	N1	01/07/11
Azobenzene	<100	197	194	200	99%	97%	70 - 130	2%	20		N1	N1	01/07/11
Benz[a]anthracene	<100	186	176	200	93%	88%	70 - 130	6%	20		N1	N1	01/07/11
Benzo[a]pyrene	<100	181	176	200	91%	88%	70 - 130	3%	20		N1	N1	01/07/11
Benzo[b]fluoranthene	<100	177	171	200	89%	86%	70 - 130	3%	20		N1	N1	01/07/11
Benzo[g,h,i]perylene	<100	175	171	200	88%	86%	70 - 130	2%	20		N1	N1	01/07/11
Benzo[k]fluoranthene	<100	201	193	200	101%	97%	70 - 130	4%	20		N1	N1	01/07/11
Benzoic acid	<1500	343	382	400	86%	96%	70 - 130	11%	20		N1	N1	01/07/11
Benzyl alcohol	<100	178	176	200	89%	88%	70 - 130	1%	20		N1	N1	01/07/11
Bis(2-chloroethoxy)methane	<100	184	190	200	92%	95%	70 - 130	3%	20		N1	N1	01/07/11
Bis(2-chloroethyl)ether	<100	194	194	200	97%	97%	70 - 130	<1%	20		N1	N1	01/07/11
Bis(2-chloroisopropyl)ether	<100	199	194	200	100%	97%	70 - 130	3%	20		N1	N1	01/07/11
Bis(2-ethylhexyl)phthalate	<100	205	189	200	103%	95%	70 - 130	8%	20		N1	N1	01/07/11
4-Bromophenyl phenyl ether	<100	182	192	200	91%	96%	70 - 130	5%	20		N1	N1	01/07/11
Butyl benzyl phthalate	<100	194	181	200	97%	91%	70 - 130	7%	20		N1	N1	01/07/11
4-Chloro-3-methylphenol	<100	372	375	400	93%	94%	70 - 130	1%	20		N1	N1	01/07/11
4-Chloroaniline	<200	206	210	200	103%	105%	70 - 130	2%	20		N1	N1	01/07/11
2-Chloronaphthalene	<100	186	189	200	93%	95%	70 - 130	2%	20		N1	N1	01/07/11
2-Chlorophenol	<100	375	375	400	94%	94%	70 - 130	<1%	20		N1	N1	01/07/11
4-Chlorophenyl phenyl ether	<100	188	192	200	94%	96%	70 - 130	2%	20		N1	N1	01/07/11
Chrysene	<100	189	181	200	95%	91%	70 - 130	4%	20		N1	N1	01/07/11
Di-n-butyl phthalate	<100	192	193	200	96%	97%	70 - 130	1%	20		N1	N1	01/07/11
Di-n-octyl phthalate	<100	198	185	200	99%	93%	70 - 130	7%	20		N1	N1	01/07/11

XENCO Laboratories
Trans West Analytical Services

QC SUMMARY REPORT

Client - Southwest Research Institute
Work Order - 00402000
Project -

MB, LCS, LCSD REPORT

Analyte	MB Result	LCS Result	LCSD Result	Spike Value	LCS REC	LCSD REC	Low - High % Limit	% RPD	RPD Limit	MB Qual	LCS Qual	LCSD Qual	Date Analyzed
Dibenz[a,h]anthracene	<100	173	167	200	87%	84%	70 - 130	4%	20		N1	N1	01/07/11
Dibenzofuran	<100	190	191	200	95%	96%	70 - 130	1%	20		N1	N1	01/07/11
1,2-Dichlorobenzene	<100	187	187	200	94%	94%	70 - 130	<1%	20		N1	N1	01/07/11
1,3-Dichlorobenzene	<100	189	190	200	95%	95%	70 - 130	1%	20		N1	N1	01/07/11
1,4-Dichlorobenzene	<100	191	193	200	96%	97%	70 - 130	1%	20		N1	N1	01/07/11
3,3`-Dichlorobenzidine	<500	159	155	200	80%	78%	70 - 130	3%	20		N1	N1	01/07/11
2,4-Dichlorophenol	<100	356	369	400	89%	92%	70 - 130	4%	20		N1	N1	01/07/11
Diethyl phthalate	<100	193	192	200	97%	96%	70 - 130	1%	20		N1	N1	01/07/11
Dimethyl phthalate	<100	190	192	200	95%	96%	70 - 130	1%	20		N1	N1	01/07/11
2,4-Dimethylphenol	<100	344	355	400	86%	89%	70 - 130	3%	20		N1	N1	01/07/11
4,6-Dinitro-2-methylphenol	<200	325	360	400	81%	90%	70 - 130	10%	20		N1	N1	01/07/11
2,4-Dinitrophenol	<100	277	315	400	69%	79%	70 - 130	13%	20		N1	N1	01/07/11
2,4-Dinitrotoluene	<100	190	195	200	95%	98%	70 - 130	3%	20		N1	N1	01/07/11
2,6-Dinitrotoluene	<100	189	194	200	95%	97%	70 - 130	3%	20		N1	N1	01/07/11
Fluoranthene	<100	183	187	200	92%	94%	70 - 130	2%	20		N1	N1	01/07/11
Fluorene	<100	191	190	200	96%	95%	70 - 130	1%	20		N1	N1	01/07/11
Hexachlorobenzene	<100	178	189	200	89%	95%	70 - 130	6%	20		N1	N1	01/07/11
Hexachlorobutadiene	<100	161	168	200	81%	84%	70 - 130	4%	20		N1	N1	01/07/11
Hexachlorocyclopentadiene	<100	196	200	200	98%	100%	70 - 130	2%	20		N1	N1	01/07/11
Hexachloroethane	<100	192	193	200	96%	97%	70 - 130	1%	20		N1	N1	01/07/11
Indeno[1,2,3-cd]pyrene	<100	176	170	200	88%	85%	70 - 130	3%	20		N1	N1	01/07/11
Isophorone	<100	198	200	200	99%	100%	70 - 130	1%	20		N1	N1	01/07/11
2-Methylnaphthalene	<100	182	186	200	91%	93%	70 - 130	2%	20		N1	N1	01/07/11
2-Methylphenol	<100	377	377	400	94%	94%	70 - 130	<1%	20		N1	N1	01/07/11
4-Methylphenol	<100	372	375	400	93%	94%	70 - 130	1%	20		N1	N1	01/07/11
N-Nitrosodi-n-propylamine	<100	194	191	200	97%	96%	70 - 130	2%	20		N1	N1	01/07/11
N-Nitrosodiphenylamine	<100	190	192	200	95%	96%	70 - 130	1%	20		N1	N1	01/07/11
Naphthalene	<100	189	193	200	95%	97%	70 - 130	2%	20		N1	N1	01/07/11
Nitrobenzene	<100	190	195	200	95%	98%	70 - 130	3%	20		N1	N1	01/07/11
2-Nitrophenol	<100	358	375	400	90%	94%	70 - 130	5%	20		N1	N1	01/07/11
4-Nitrophenol	<300	366	370	400	92%	93%	70 - 130	1%	20		N1	N1	01/07/11
Pentachlorophenol	<200	324	346	400	81%	87%	70 - 130	7%	20		N1	N1	01/07/11
Phenanthrene	<100	187	190	200	94%	95%	70 - 130	2%	20		N1	N1	01/07/11
Phenol	<100	376	374	400	94%	94%	70 - 130	1%	20		N1	N1	01/07/11
Pyrene	<100	188	179	200	94%	90%	70 - 130	5%	20		N1	N1	01/07/11
1,2,4-Trichlorobenzene	<100	195	206	200	98%	103%	70 - 130	5%	20		N1	N1	01/07/11
2,4,6-Trichlorophenol	<100	358	366	400	90%	92%	70 - 130	2%	20		N1	N1	01/07/11
2-Chlorophenol-d4	91%	271	265	300	90%	88%	52 - 148						01/07/11
1,2-Dichlorobenzene-d4	92%	179	179	200	90%	90%	54 - 148						01/07/11
2-Fluorobiphenyl	91%	178	177	200	89%	89%	54 - 142						01/07/11
2-Fluorophenol	91%	270	263	300	90%	88%	54 - 144						01/07/11
Nitrobenzene-d5	92%	180	180	200	90%	90%	50 - 151						01/07/11
Phenol-d6	91%	273	268	300	91%	89%	51 - 149						01/07/11
4-Terphenyl-d14	93%	178	167	200	89%	84%	58 - 144						01/07/11
2,4,6-Tribromophenol	61%	253	259	300	84%	86%	34 - 139						01/07/11

402000

SOUTHWEST RESEARCH INSTITUTE

9503 W. COMMERCE - SAN ANTONIO, TX 78227-1301
(210) 684-5111

SHIPPING TICKET NO.
69370
(THIS IS NOT A P.O. NO.)
DATE: 12/28/10

PRIOR TO REPAIR OF ANY ITEM MENTIONED BELOW, PLEASE CONTACT 210/522-3074 WITH ESTIMATE AND FOR P.O. NO.

SHIP TO:
Xenco Laboratories
3725 E. Atlanta Ave.
Phoenix, AZ 85040

Tel: 602-437-0330

ATTN: Skip Harden

VENDOR PHONE NO. | R.M.A. NO.

Please check box for method of shipment to and from Vendor
Circle specific method of shipment by Air Freight or UPS

SHIP VIA	TO VENDOR	RETURN TO SWRI
MOTOR FREIGHT	☐	☐
AIR FREIGHT (PRIORITY AIR GENERAL CARGO)	☐	☐
UPS (1 day, 2days or 7-10 days)	☐	☐
FEDERAL EXPRESS (1 day, 2 days)	☒	☐
OTHER	☐	☐

PPD. ☒ COLL ☐	INSURE FOR $ 0.00	DECLARED VALUE $ 0.00	GOVT. PROJ. ☐	DEPT NO. 08	PURCHASE ORDER NO.

AIR BILL OR W/B NO.	ACCT. OR PROJECT NO. 1.08.07.13.16246.05.001	SWRI REQ. NO.	RETURN INITIATED BY Hutzler/pgl	EXT.

QUANTITY	DESCRIPTION & SERIAL NO.	ORIGINAL P.O., S.O., R.O., C.O.D./REQ. NO./B/O
	EOT Date	
	JET FUEL	
	1 EACH - 50mL SAMPLE CODED CL10-1818	
	FLAMMABLE LIQUID	

S.W.R.I. BUYER | BUYER NOTIFIED ☐ | Please indicate if items are HAZARDOUS MATERIAL ☒ YES ☐ NO

NO. OF PACKAGES 1 | TYPE OF PACKAGE ☒ BOX ☐ CTN ☐ DRUM ☐ ______ | WEIGHT | DIMENSIONS

REASON FOR SHIPMENT AND/OR REMARKS

☐ **REPAIR** (INDICATE PROBLEM IN REMARKS AREA) ☐ **WARRANTY** ☐ **CREDIT** ☐ **CREDIT LESS RESTOCKING CHG.** ☐ **EXCHANGE** ☐ **OTHER** (EXPLAIN IN REMARKS AREA)

REMARKS

DATE SHIPPED | VENDOR RECEIPT BY: rec'd 12/29/10 0955 Leslie May - Xenco/Phx

THIS FORM TO BE USED FOR ANYTHING SHIPPED FROM S.W.R.I.

IMPORTANT

PACKING LIST (PINK COPY) SHOULD BE ATTACHED TO THE OUTSIDE OF THE CONTAINER. REMAINDER OF SHIPPING TICKET SHOULD BE RETURNED TO SHIPPING & RECEIVING. PT.5 (GOLDENROD COPY) WILL BE RETURNED TO YOU FOR DEPARTMENT RECORDS.

SHIPPING COPY

Container type : 250

XENCO Laboratories

Sample Receipt Checklist

Client Name: SW Research Institute | Date and Time Received: 12/29/10 0955

Work Order Number: 402000 | Checked by: lm

Checklist completed by: Leslie May Date: 12/29/10 | Logged In by: lm Date: 12/29/10

Matrix: Liq Courier Name: Client Xenco FedEx | Reviewed by: ____ Date: ____

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐	
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑	
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑	
Chain of custody signed when relinquished and received?	Yes ☐	No ☑	Not Present ☐	
Chain of custody agrees with sample labels?	Yes ☐	No ☐		
Samples in proper container/bottle?	Yes ☐	No ☐		
Sample containers intact?	Yes ☑	No ☐		
Sufficient sample volume for indicated test?	Yes ☑	No ☐		
All samples received within holding time?	Yes ☐	No ☐		
Samples received same day of collection?	Yes ☐	No ☑	Temp: 12.2	Wet Ice Present ☐
Where was the temperature reading taken at?	Sample ☑	Temp Blank ☐	Other:	
VOA Water – VOA vials have zero headspace?	Yes ☐	No ☐	N/A ☑	
Water – Microbiological bottles have ≤ 2.5 cm headspace?	Yes ☐	No ☐	N/A ☑	
Water – All sample pH's acceptable upon receipt?	Yes ☐	No ☐	N/A ☑	Checked by: ____

If **No**, list all samples and bottle types that are not acceptable in Additional Comments section. Also state any correction actions.

Sulfide Water – Bottles have zero headspace?	Yes ☐	No☐	N/A ☑	(zero headspace ≤ than neck of bottle)
Dissolved Water Analytes – Field Filtered?	Yes ☐	No☐	N/A ☑	
Are samples received deemed acceptable?	Yes ☐	No ☑	If **No** then complete section below	

PC Notified	Date: ____	Init: ____	PC Init: ____			
Client Notified	Date: ____	Init: ____	L/M ☐	Date: ____	L/M ☐	Date: ____
Contact Name: ____		Action to take:	Analyze ☐	Cancel ☐	Hold ☐	Other:
Changes/Comments made on original COC?			Yes ☐	N/A ☐	Init: ____	Date: ____
Changes made in LIMS?			Yes ☐	N/A ☐	Init: ____	Date: ____

Additional Comments: no COC, no date or time sampled

CS-002-SRChecklist RV5

Appendix E-4

Rentech FT-SPK

Table E-6. Rentech FT SPK and Rentech / JP-8 Evaluations

Test	Method	Units	CL11-2183 Rentech / JP-8 Blend (POSF7458)	CL11-2185 Rentech FT-SPK (POSF7457)
Chemistry				
Hydrocarbon Types by Mass Spec	D2425			
Paraffins		mass%	66.3	89.9
Monocycloparaffins		mass%	21.8	8.7
Dicycloparaffins		mass%	0.0	0.3
Tricycloparaffins		mass%	0.0	0.0
TOTAL SATURATES		mass%	88.1	98.9
Alkylbenzenes		mass%	6.8	0.8
Indans/Tetralins		mass%	3.5	0.3
Indenes		mass%	0.5	0.0
Naphthalene		mass%	0.4	0.0
Naphthalene, Alklyl		mass%	0.5	0.0
Acenaphthenes		mass%	0.1	0.0
Acenaphthylenes		mass%	0.1	0.0
Tricyclic Aromatics		mass%	0.0	0.0
TOTAL AROMATICS		mass%	11.9	1.1
Aromatic Content	D1319			
Aromatics		vol%	10.4	1.6
Olefins		vol%	1.8	1.1
Saturates		vol%	87.8	97.3
Carbon/Hydrogen	D5291			
Carbon		%	85.61	84.66
Hydrogen		%	14.63	15.27
Hydrogen Content (NMR)	D3701	mass%	14.69	15.35
Carbonyls, Alcohols, Esters, Phenols				
Alcohols	EPA 8015B		See Report Below	See Report Below
Carbonyls, Esters	EPA 8260B			
Phenols	EPA 8270C			
Nitrogen Content	D4629	mg/kg	3	1
Copper by AA	D3237M	ppb	24	24
Elemental Analysis	UOP 389			
Al		ppm	<0.02	<0.02
Ca		ppm	0.41	0.31
Co		ppm	<0.02	<0.02
Cr		ppm	<0.02	<0.02
Cu		ppm	<0.02	<0.02
Fe		ppm	0.04	0.04

Table E-6. Rentech FT SPK and Rentech / JP-8 Evaluations

Test	Method	Units	CL11-2183 Rentech / JP-8 Blend (POSF7458)	CL11-2185 Rentech FT-SPK (POSF7457)
K		ppm	0.02	<0.02
Li		ppm	<0.02	<0.02
Mg		ppm	<0.02	<0.02
Mn		ppm	<0.02	<0.02
Mo		ppm	<0.02	<0.02
Na		ppm	<0.02	0.10
Ni		ppm	<0.02	<0.02
P		ppm	<0.02	<0.02
Pb		ppm	<0.02	<0.02
Pd		ppm	<0.02	<0.02
Pt		ppm	<0.02	<0.02
Sn		ppm	<0.02	<0.02
Sr		ppm	<0.02	<0.02
Ti		ppm	<0.02	<0.02
V		ppm	<0.02	<0.02
Zn		ppm	<0.02	<0.02
Bulk Physical and Performance Properties				
Distillation	D86			
IBP		°C	143.1	137.2
5%		°C	168.8	162.8
10%		°C	173.7	165.4
15%		°C	179.2	171.5
20%		°C	184.0	177.0
30%		°C	193.5	189.2
40%		°C	202.1	202.6
50%		°C	210.6	216.2
60%		°C	219.9	229.0
70%		°C	229.2	240.9
80%		°C	240.1	252.1
90%		°C	253.3	263.8
95%		°C	262.9	271.0
FBP		°C	266.9	273.1
Residue		%	1.4	1.5
Loss		%	1.2	1.4
T50-T10		°C	36.9	50.8
T90-T10		°C	79.6	98.4
Simulated Distillation	D2887			
IBP		°C	103.2	*N/A*
5%		°C	142.2	*N/A*
10%		°C	152.4	*N/A*
15%		°C	166.1	*N/A*

Table E-6. Rentech FT SPK and Rentech / JP-8 Evaluations

Test	Method	Units	CL11-2183 Rentech / JP-8 Blend (POSF7458)	CL11-2185 Rentech FT-SPK (POSF7457)
20%		°C	174.0	*N/A*
25%		°C	181.0	*N/A*
30%		°C	188.5	*N/A*
35%		°C	195.8	*N/A*
40%		°C	200.8	*N/A*
45%		°C	208.1	*N/A*
50%		°C	214.4	*N/A*
55%		°C	219.1	*N/A*
60%		°C	226.6	*N/A*
65%		°C	232.6	*N/A*
70%		°C	238.4	*N/A*
75%		°C	246.3	*N/A*
80%		°C	254.0	*N/A*
85%		°C	262.1	*N/A*
90%		°C	271.1	*N/A*
95%		°C	281.7	*N/A*
FBP		°C	313.0	*N/A*
Vapor Pressure (Absolute)	D6378			
0 °C		psi	0.13	0.12
10 °C		psi	0.21	0.17
20 °C		psi	0.26	0.22
30 °C		psi	0.33	0.28
40 °C		psi	0.43	0.35
50 °C		psi	0.56	0.45
60 °C		psi	0.74	0.60
70 °C		psi	1.00	0.81
80 °C		psi	1.32	1.09
90 °C		psi	1.75	1.47
100 °C		psi	2.31	1.98
110 °C		psi	3.03	2.63
120 °C		psi	3.99	3.49
JFTOT Breakpoint	D3241BP	°C		
Test Temperature		°C	290	--
ASTM Code		rating	<3	--
Maximum Pressure Drop		mm Hg	1.0	--
JFTOT @ 325°C	D3241BP	°C		
Test Temperature		°C	--	325
ASTM Code		rating	--	<3
Maximum Pressure Drop		mm Hg	--	0.0
Lubricity (BOCLE)	D5001	mm	0.53	0.60
Lubricity (BOCLE) vs. CI/LI Concentration	D5001			

Table E-6. Rentech FT SPK and Rentech / JP-8 Evaluations

Test	Method	Units	CL11-2183 Rentech / JP-8 Blend (POSF7458)	CL11-2185 Rentech FT-SPK (POSF7457)
0 mg/L		mm	0.73	0.77
5 mg/L		mm	0.60	0.68
10 mg/L		mm	0.52	0.58
15 mg/L		mm	0.52	0.53
20 mg/L		mm	0.48	0.51
Lubricity (HFRR)	D6079	mm	0.68	*N/A*
Lubricity (HFRR) vs. CI/LI Concentration	D6079			
0 mg/L		mm	0.71	*N/A*
5 mg/L		mm	0.69	*N/A*
10 mg/L		mm	0.70	*N/A*
15 mg/L		mm	0.70	*N/A*
20 mg/L		mm	0.76	*N/A*
Lubricity (Scuffing Load BOCLE)	D6078	mm	2550	*N/A*
Lubricity (Scuffing Load BOCLE) vs. CI/LI Concentration	D6078			
0 mg/L		g	2050	*N/A*
5 mg/L		g	2000	*N/A*
10 mg/L		g	2550	*N/A*
15 mg/L		g	2150	*N/A*
20 mg/L		g	2350	*N/A*
Kinematic Viscosity	D445			
-39.95°C		cSt	9.93	10.79
-19.98°C		cSt	4.73	5.02
25°C		cSt	1.70	1.77
40°C		cSt	1.35	1.40
Specific Heat Capacity	E2716			
-25°C		kJ/kg.K	1.734	*N/A*
0°C		kJ/kg.K	1.803	*N/A*
25°C		kJ/kg.K	1.880	*N/A*
50°C		kJ/kg.K	1.962	*N/A*
100°C		kJ/kg.K	2.114	*N/A*
150°C		kJ/kg.K	2.371	*N/A*
Density	D4052			
5°C		g/cm^3	0.7897	0.7695
15°C		g/cm^3	0.7823	0.7618
40°C		g/cm^3	0.7642	0.7438
60°C		g/cm^3	0.7492	0.7290
80°C		g/cm^3	0.7342	0.7141
Surface tension	D1331A			
-8.9°C		mN/m	27.6	*N/A*
22°C		mN/m	25.1	*N/A*
40.1°C		mN/m	23.4	*N/A*

Table E-6. Rentech FT SPK and Rentech / JP-8 Evaluations

Test	Method	Units	CL11-2183 Rentech / JP-8 Blend (POSF7458)	CL11-2185 Rentech FT-SPK (POSF7457)
Speed of Sound @ 30°C		m/s	1260	1246
Isentropic Bulk Modulus @ 30°C		psig	177706	169015
Thermal Conductivity	SwRI			
0°C		W/m.K	0.113	*N/A*
25°C		W/m.K	0.112	*N/A*
50°C		W/m.K	0.110	*N/A*
Water Content	D6304	ppm	132	135
Water Content	D6304			
-9°C		ppm	178	*N/A*
36.5°C		ppm	193	*N/A*
45°C		ppm	201	*N/A*
-7.2°C		ppm	*N/A*	101
35.5°C		ppm	*N/A*	164
45°C		ppm	*N/A*	232
Flash Point – Tag Closed	D56	°C	47	45
Freeze Point (manual)	D2386	°C	-52.0	*N/A*
Freeze Point	D5972	°C	-50.8	-49.8
Electrical Properties				
Dielectric Constant (10kHz)	SwRI			
-40°C		---	2.164	--
-20°C		---	2.135	--
0°C		---	2.108	--
30°C		---	2.074	--
50°C		---	2.047	--
-35°C		---	--	2.105
-20.8°C		---	--	2.088
0°C		---	--	2.062
30°C		---	--	2.029
50.9°C		---	--	2.003
Electrical Conductivity	D2624	pS/m	455.0	806.0
Electrical Conductivity vs. SDA Concentration	D2624			
0 mg/L		pS/m	0	1
1 mg/L		pS/m	287	459
2 mg/L		pS/m	549	860
3 mg/L		pS/m	853	1273
4 mg/L		pS/m	1136	1759
Electrical Conductivity vs. Temperature	D2624			
-40		pS/m	70.0	*N/A*
-30		pS/m	126.0	*N/A*
-20		pS/m	--	*N/A*
-10		pS/m	158.0	*N/A*

Table E-6. Rentech FT SPK and Rentech / JP-8 Evaluations

Test	Method	Units	CL11-2183 Rentech / JP-8 Blend (POSF7458)	CL11-2185 Rentech FT-SPK (POSF7457)
0		pS/m	208.0	*N/A*
10		pS/m	322.0	*N/A*
20		pS/m	433.0	*N/A*
30		pS/m	572.0	*N/A*
40		pS/m	817.0	*N/A*
50		pS/m	946.0	*N/A*
Ground Handling Properties and Safety				
MSEP	D3948	rating	49	*N/A*
Removal of Emulsified Water	SAE J1488	TWA WRE **	*See Below*	*N/A*
Storage Stability – Peroxides @65°C	D3703			
0 week		mg/kg	2.00	*N/A*
1 week		mg/kg	0.48	*N/A*
2 week		mg/kg	1.92	*N/A*
3 week		mg/kg	2.08	*N/A*
6 week		mg/kg	2.16	*N/A*
Storage Stability – Potential Gums	D5304			
16 hours		mg/100mL	3.3	2.4
Upper Explosion Limit (UEL), @100°C	E681	%	4.8 ± 0.1	*N/A*
Lower Explosion Limit (LEL), @100°C	E681	%	0.3 ± 0.1	*N/A*
Autoignition temperature	E659			
Hot Flame Autoignition Temperature		°C	267.0	*N/A*
Hot Flame Lag Time		seconds	7.4	*N/A*
Cool Flame Autoignition Temperature		°C	219.0	*N/A*
Cool Flame Lag Time		seconds	276.0	*N/A*
Barometric Pressure		mm Hg	743.6	*N/A*
Reaction Threshold Temperature		°C	210.0	*N/A*
Hot Surface Ignition	FTM 791-6053	°F	1200	*N/A*
Compatibility				
Fuel/Additive Compatibility (4x treat rate)	D4054B			
FSII		effect	some separation when cold	some separation when cold
SDA		effect	no separation observed	no separation observed
CI/LI		effect	no separation observed	film on bottom after cooling
MDA		effect	no separation observed	no separation observed
AO		effect	small beads after cooling	small beads after cooling
+100		effect	no separation observed	no separation observed
Additive Cocktail (MDA, AO, SDA, CI/LI, FSII,+100)		effect	film on bottom after cooling	film on bottom after cooling
Elastomer Compatibility (O-Ring Tests)	SwRI		*See Figure E-35, Figure E-36, Figure E-37*	*N/A*
Miscellaneous				
Copper Strip Corrosion (100°C for 2 hours)	D130	rating	1B	1B
Smoke Point	D1322	mm	27.0	*N/A*

Table E-6. Rentech FT SPK and Rentech / JP-8 Evaluations

Test	Method	Units	CL11-2183 Rentech / JP-8 Blend (POSF7458)	CL11-2185 Rentech FT-SPK (POSF7457)
Naphthalene Content	D1840	vol%	0.49	*N/A*
Sulfur – Mercaptan	D3227	mass%	<0.0003	<0.0003
Acid Number	D3242	mg KOH/g	0.017	0.016
Existent Gums	D381	mg/100mL	<0.5	6.70
Heat of Combustion	D4809			
BTUHeat_Gross		BTU/lb	20063.6	*N/A*
BTUHeat_Net		BTU/lb	18723.4	*N/A*
MJHeat_Gross		MJ/kg	46.7	*N/A*
MJHeat_Net		MJ/kg	43.5	*N/A*
Sulfur Content – (Antek)	D5453	ppm	180	0
Ignition Quality Test (IQT)	D6890			
Ignition Delay, ID		ms	3.950	*N/A*
Derived Cetane Number, DCN			51.7	*N/A*
Minimum Ignition Energy @ 100°C	E582	mJ	0.76	*N/A*
Sulfur Content – (XRY)	D2622	ppm	194	*N/A*

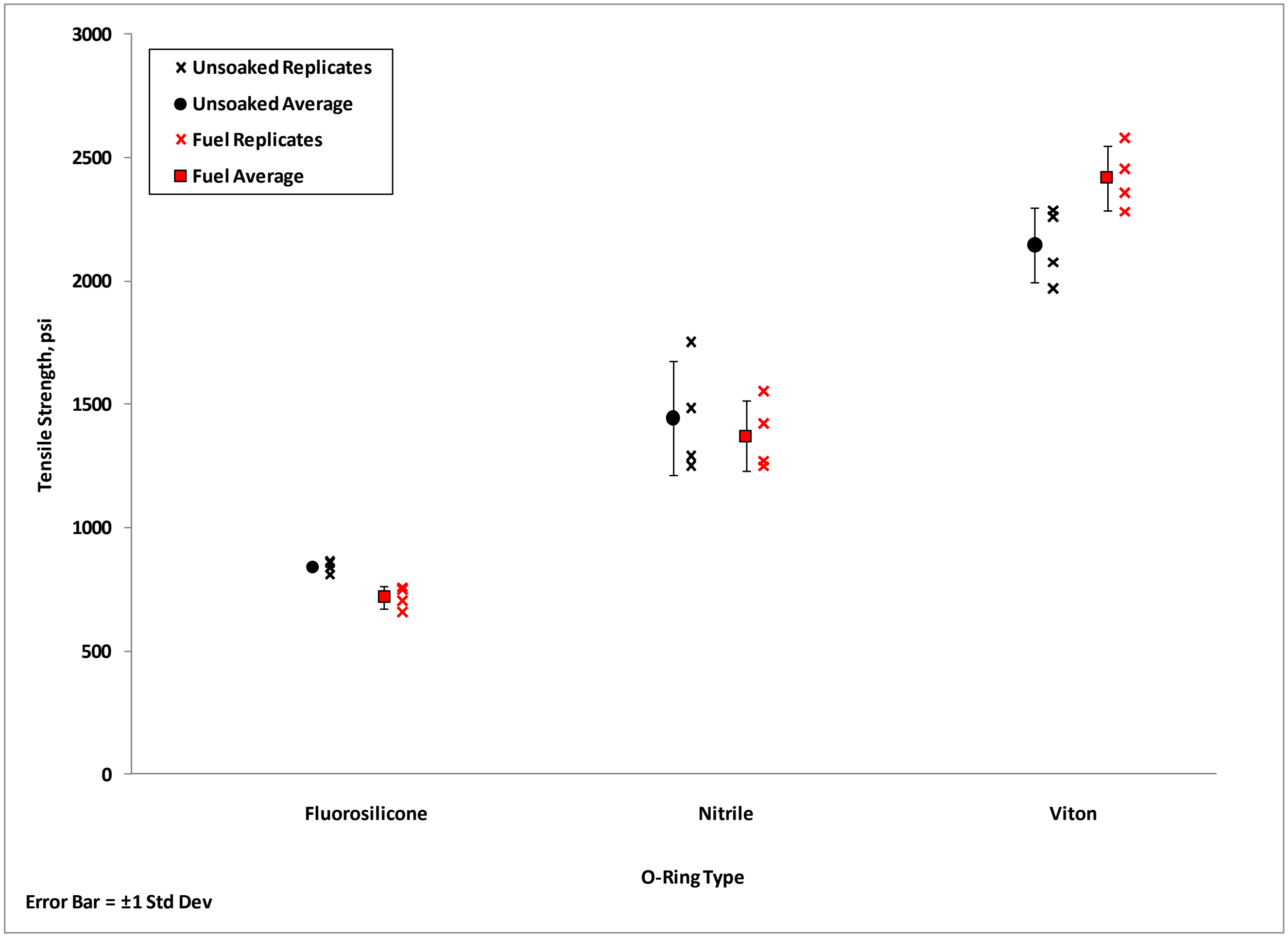

Figure E-35. Rentech / JP-8 (CL11-2183) O-Ring Data – Tensile Strength

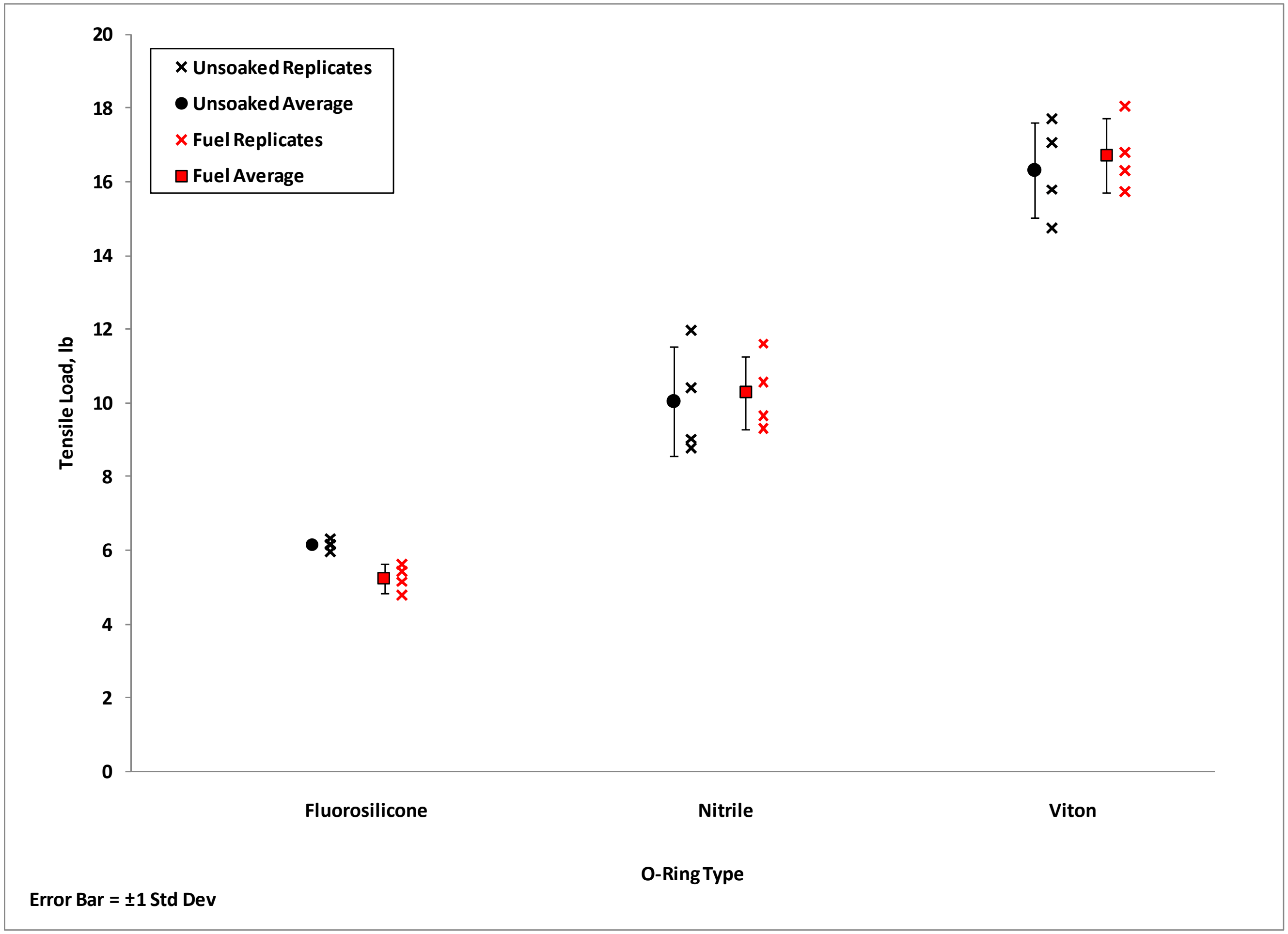

Figure E-36. Rentech / JP-8 (CL11-2183) O-Ring Data – Tensile Load

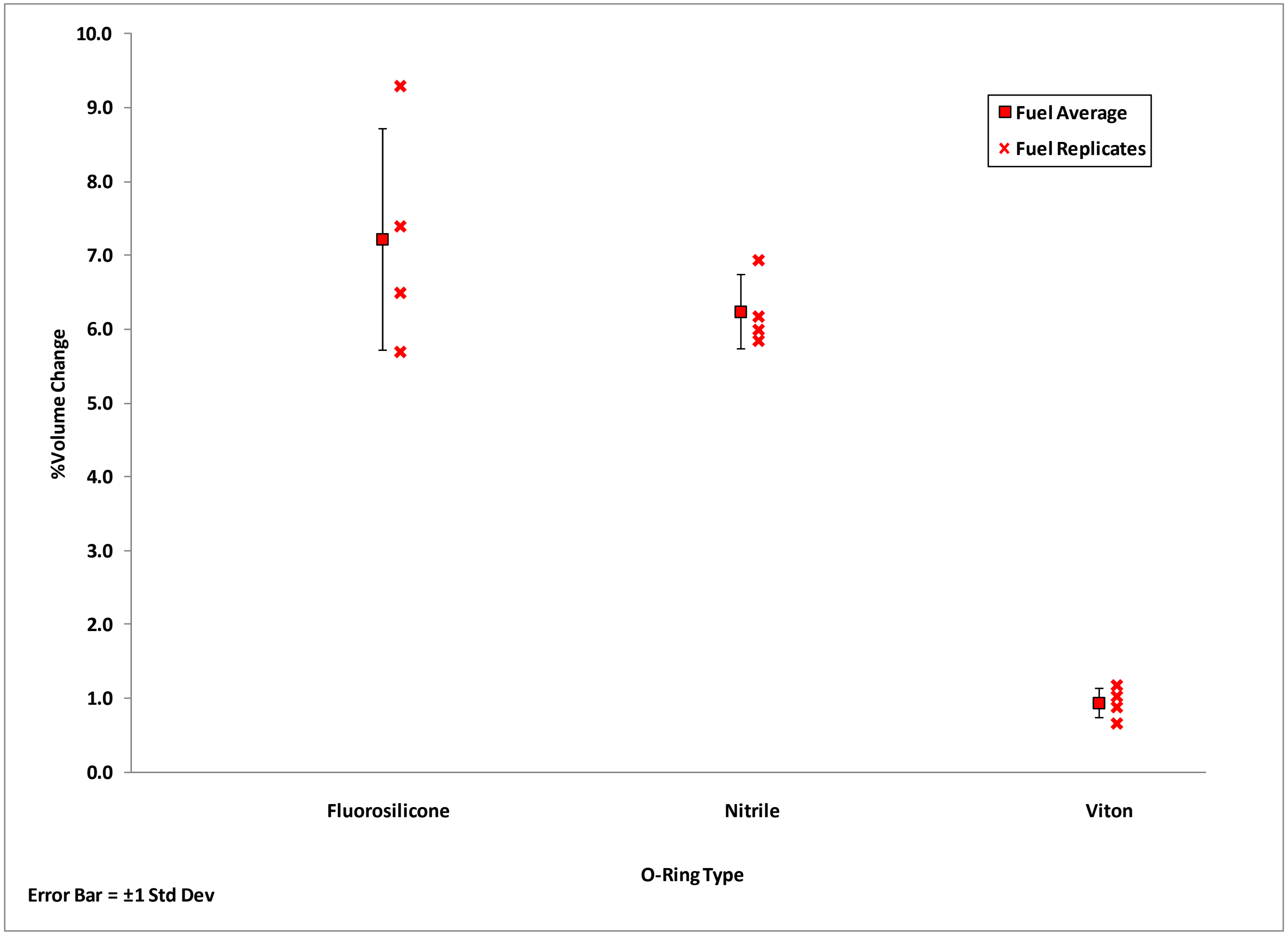

Figure E-37. Rentech / JP-8 (CL11-2183) O-Ring Data – Volume Change

SAE J1488 Test Report – CL11-2183 (Rentech/JP-8 Blend)

Test Description	SAE J1488	**Test No**	1
Test Engineer		**Filter ID, Sponsor**	M1A1
Test Fluid	POSF 7458	**Test Date**	3/30/2011
Vacuum/ Pressure	Pressure	**Test Temperature, C**	26
Test Fluid Flow Rate (lpm)	7.6	**Water Saturation**	89
Water Injection Rate (ml/min)	19	**SwRI Filter ID**	
		Work Order No	100657

Average Upstream Water Content, ppm	2138
Time Weighted Average Water Removal Efficiency(%)	99.9
Total Water from Test Housing(ml)	2135
Water from Cleanup filters(ml)	0

Fuel/Water Interfacial Tension(mN/m)	
Before	33.3
After	35.7
MSEP	
Before	97
After	96

Sample ID	Test Time (minutes)	Upstream (ppm)	Downstream Water Content (ppm)		Pressure Drop (kPa)	Water Drained from test filter (mL)
1	0	90	0	0	10	-
2	10	1659	91	2	12	0
3	30	1752	95	6	12	0
4	50	3534	94	4	12	380
5	70	2120	77	0	12	590
6	90	2070	74	0	13	190
7	110	1761	89	0	13	300
8	130	1745	101	12	13	335
9	150	2458	85	0	13	340

Note: An issue with the water injection system during this test caused the total injected water to be less than required. Due to limited availability of fuel, we chose not to abort the test else we would have obtained no data at all. Overall, the total injected water amount was approximately 2.8% less than required. However, since the water removal efficiency was nearly 100%, we feel this is still representative of the ability to remove water from this fuel using a typical fuel filtration system.

Analytical Report 407165

for

Southwest Research Institute

Project Manager: Scott Hutzler

Phoenix XENCO - Master Project

1.08.07.13.16246.05

28-APR-11

XENCO Laboratories
Trans West Analytical Services, LLC

Celebrating 20 Years of commitment to excellence in Environmental Testing Services

3725 E. Atlanta Ave, Phoenix, AZ 85040
Ph: (602) 437-0330

Xenco-Houston (EPA Lab code: TX00122):
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Xenco Tucson (EPA Lab code:AZ000989): Arizona (AZ0758)

28-APR-11

Project Manager: **Scott Hutzler**
Southwest Research Institute
6220 Culebra Road
P.O. Box 28510
San Antonio, TX 78228

Reference: XENCO Report No: **407165**
Phoenix XENCO - Master Project
Project Address:

Scott Hutzler :

We are reporting to you the results of the analyses performed on the samples received under the project name referenced above and identified with the XENCO Report Number 407165. All results being reported under this Report Number apply to the samples analyzed and properly identified with a Laboratory ID number. Subcontracted analyses are identified in this report with either the NELAC certification number of the subcontract lab in the analyst ID field, or the complete subcontracted report attached to this report.

Unless otherwise noted in a Case Narrative, all data reported in this Analytical Report are in compliance with NELAC standards. Estimation of data uncertainty for this report is found in the quality control section of this report unless otherwise noted. Should insufficient sample be provided to the laboratory to meet the method and NELAC Matrix Duplicate and Matrix Spike requirements, then the data will be analyzed, evaluated and reported using all other available quality control measures.

The validity and integrity of this report will remain intact as long as it is accompanied by this letter and reproduced in full, unless written approval is granted by XENCO Laboratories. This report will be filed for at least 5 years in our archives after which time it will be destroyed without further notice, unless otherwise arranged with you. The samples received, and described as recorded in Report No. 407165 will be filed for 60 days, and after that time they will be properly disposed without further notice, unless otherwise arranged with you. We reserve the right to return to you any unused samples, extracts or solutions related to them if we consider so necessary (e.g., samples identified as hazardous waste, sample sizes exceeding analytical standard practices, controlled substances under regulated protocols, etc).

We thank you for selecting XENCO Laboratories to serve your analytical needs. If you have any questions concerning this report, please feel free to contact us at any time.

Respectfully,

Skip Harden, Jr.
Project Manager

Recipient of the Prestigious Small Business Administration Award of Excellence in 1994.
Certified and approved by numerous States and Agencies.
A Small Business and Minority Status Company that delivers SERVICE and QUALITY

Houston - Dallas - San Antonio - Austin - Tampa - Miami - Atlanta - Corpus Christi - Latin America

CASE NARRATIVE

XENCO Laboratories
Trans West Analytical Services, LLC

Client Name: Southwest Research Institute
Project Name: Phoenix XENCO - Master Project

Project ID:	*1.08.07.13.16246.05*	*Report Date:*	*28-APR-11*
Work Order Number:	*407165*	*Date Received:*	*02/18/2011*

Sample receipt non conformances and Comments:

None

Sample receipt Non Conformances and Comments per Sample:

None

Analytical Non Conformances and Comments:

Batch: LBA-844840 VOCs by EPA 8260B
S10:
Due to sample matrix interference, the surrogates recovered above acceptance criteria.

Batch: LBA-845089 SVOCs by SW846 8270
N1:
2,4,6-Tribromophenol recovered below acceptance criteria in the Blank. Low surrogate was confirmed with re-analysis.
N1:
Since the sample chosen for MS/MSD would have needed such a high dilution that the information provided would have been useless, the MS/MSD were not analyzed.

XENCO Laboratories

Flagging Criteria

Arizona Flags

All method blanks, laboratory spikes, and/or matrix spikes met quality control objectives for the parameters associated with this Work Order except as detailed below or on the Data Qualifier page of this report. Data Qualifiers used in this report are in accordance with ADEQ Arizona Data Qualifiers, Revision 3.0 9/20/2007. Data qualifiers (flags) contained within this analytical report have been issued to explain a quality control deficiency, and do not affect the quality (validity) of the data unless noted otherwise in the case narrative.

D1 Sample required dilution due to matrix.

D2 Sample required dilution due to high concentration of target analyte.

M1 Matrix spike recovery was high; the associated blank spike recovery was acceptable.

N1 See case narrative.

S10 Surrogate recovery was above laboratory and method acceptance limits. See case narrative.

S8 The analysis of the sample required a dilution such that the surrogate recovery calculation does not provide any useful information. The associated blank spike recovery was acceptable.

XENCO Laboratories
Trans West Analytical Services, LLC

Sample Cross Reference 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id	Matrix	Date Collected	Sample Depth	Lab Sample Id
CL11-2183	O	Feb-17-11 00:00		407165-001
CL11-2185	O	Feb-17-11 00:00		407165-002

XENCO Laboratories
Trans West Analytical Services, LLC

Certificate of Analytical Results 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id: CL11-2183 **Matrix:** Oil **Date Received:** Feb-18-11 18:06
Lab Sample Id: 407165-001 **Date Collected:** Feb-17-11 00:00

Analytical Method: SVOCs by SW846 8270 **Prep Method:** SW3580A
Tech: CBV **% Moisture:**
Analyst: JIH **Date Prep:** Feb-22-11 12:00
Seq Number: 845089

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Acenaphthene	83-32-9	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Acenaphthylene	208-96-8	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Anthracene	120-12-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Azobenzene	103-33-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Benzo(a)anthracene	56-55-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Benzo(a)pyrene	50-32-8	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Benzo(b)fluoranthene	205-99-2	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Benzo(g,h,i)perylene	191-24-2	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Benzo(k)fluoranthene	207-08-9	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Benzoic Acid	65-85-0	<4000	4000	mg/kg	02/23/11 21:33	D1	20
Benzyl Alcohol	100-51-6	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Benzyl Butyl Phthalate	85-68-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20
bis(2-chloroethoxy) methane	111-91-1	<1320	1320	mg/kg	02/23/11 21:33	D1	20
bis(2-chloroethyl) ether	111-44-4	<1320	1320	mg/kg	02/23/11 21:33	D1	20
bis(2-chloroisopropyl) ether	108-60-1	<1320	1320	mg/kg	02/23/11 21:33	D1	20
bis(2-ethylhexyl) phthalate	117-81-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20
4-Bromophenyl-phenylether	101-55-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
di-n-Butyl Phthalate	84-74-2	<1320	1320	mg/kg	02/23/11 21:33	D1	20
4-chloro-3-methylphenol	59-50-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20
4-Chloroaniline	106-47-8	<4000	4000	mg/kg	02/23/11 21:33	D1	20
2-Chloronaphthalene	91-58-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20
2-Chlorophenol	95-57-8	<1320	1320	mg/kg	02/23/11 21:33	D1	20
4-Chlorophenyl Phenyl Ether	7005-72-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Chrysene	218-01-9	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Dibenz(a,h)anthracene	53-70-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Dibenzofuran	132-64-9	<1320	1320	mg/kg	02/23/11 21:33	D1	20
1,2-Dichlorobenzene	95-50-1	<1320	1320	mg/kg	02/23/11 21:33	D1	20
1,3-Dichlorobenzene	541-73-1	<1320	1320	mg/kg	02/23/11 21:33	D1	20
1,4-Dichlorobenzene	106-46-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20
3,3-Dichlorobenzidine	91-94-1	<6800	6800	mg/kg	02/23/11 21:33	D1	20
2,4-Dichlorophenol	120-83-2	<2000	2000	mg/kg	02/23/11 21:33	D1	20
Diethyl Phthalate	84-66-2	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Dimethyl Phthalate	131-11-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
2,4-Dimethylphenol	105-67-9	<1320	1320	mg/kg	02/23/11 21:33	D1	20
4,6-dinitro-2-methyl phenol	534-52-1	<8000	8000	mg/kg	02/23/11 21:33	D1	20
2,4-Dinitrophenol	51-28-5	<8000	8000	mg/kg	02/23/11 21:33	D1	20
2,4-Dinitrotoluene	121-14-2	<1320	1320	mg/kg	02/23/11 21:33	D1	20
2,6-Dinitrotoluene	606-20-2	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Fluoranthene	206-44-0	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Fluorene	86-73-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20

XENCO Laboratories
Trans West Analytical Services, LLC

Certificate of Analytical Results 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id: CL11-2183	**Matrix:** Oil	**Date Received:** Feb-18-11 18:06
Lab Sample Id: 407165-001	**Date Collected:** Feb-17-11 00:00	

Analytical Method:	SVOCs by SW846 8270		**Prep Method:** SW3580A
Tech:	CBV		**% Moisture:**
Analyst:	JIH	**Date Prep:** Feb-22-11 12:00	
Seq Number:	845089		

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Hexachlorobenzene	118-74-1	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Hexachlorobutadiene	87-68-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Hexachlorocyclopentadiene	77-47-4	<8000	8000	mg/kg	02/23/11 21:33	D1	20
Hexachloroethane	67-72-1	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Indeno(1,2,3-c,d)Pyrene	193-39-5	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Isophorone	78-59-1	<1320	1320	mg/kg	02/23/11 21:33	D1	20
2-Methylnaphthalene	91-57-6	<1320	1320	mg/kg	02/23/11 21:33	D1	20
2-methylphenol	95-48-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Naphthalene	91-20-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Nitrobenzene	98-95-3	<1320	1320	mg/kg	02/23/11 21:33	D1	20
2-Nitrophenol	88-75-5	<1320	1320	mg/kg	02/23/11 21:33	D1	20
4-Nitrophenol	100-02-7	<8000	8000	mg/kg	02/23/11 21:33	D1	20
N-Nitrosodi-n-Propylamine	621-64-7	<1320	1320	mg/kg	02/23/11 21:33	D1	20
N-Nitrosodiphenylamine	86-30-6	<1320	1320	mg/kg	02/23/11 21:33	D1	20
di-n-Octyl Phthalate	117-84-0	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Pentachlorophenol	87-86-5	<2680	2680	mg/kg	02/23/11 21:33	D1	20
Phenanthrene	85-01-8	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Phenol	108-95-2	<1320	1320	mg/kg	02/23/11 21:33	D1	20
Pyrene	129-00-0	<1320	1320	mg/kg	02/23/11 21:33	D1	20
1,2,4-Trichlorobenzene	120-82-1	<2000	2000	mg/kg	02/23/11 21:33	D1	20
2,4,6-Trichlorophenol	88-06-2	<4000	4000	mg/kg	02/23/11 21:33	D1	20

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
2-Fluorobiphenyl	321-60-8	0	%	70-130	02/23/11 21:33	S8
2-Fluorophenol	367-12-4	0	%	70-130	02/23/11 21:33	S8
Nitrobenzene-d5	4165-60-0	0	%	70-130	02/23/11 21:33	S8
Phenol-d6	13127-88-3	0	%	70-130	02/23/11 21:33	S8
Terphenyl-D14	1718-51-0	0	%	70-130	02/23/11 21:33	S8
2,4,6-Tribromophenol	118-79-6	0	%	70-130	02/23/11 21:33	S8
2-Chlorophenol-D4	93951-73-6	0	%	70-130	02/23/11 21:33	S8
1,2-Dichlorobenzene-D4	2199-69-1	0	%	70-130	02/23/11 21:33	S8

TENTATIVELY IDENTIFIED COMPOUNDS
EPA METHOD 8270C

CLIENT:	**Southwest Research Institute**	**Client Sample ID:**	CL11-2183
Work Order:	407165	**Collection Date:**	2/17/2011
LAB ID:	407165-01A	**Matrix:**	Jet Fuel
Project Name:		**Date Prepared:**	2/17/2011
Project Number:	1.08.07.13.16246.05	**Date Analyzed:**	2/17/2011

No.	CAS #	Compound Name	Amount (mg/Kg)
1.	3221-61-2	2-methyl-ocatane	8800
2.	111-84-2	Nonane	11000
3.	124-18-5	Decane	16000
4.	1120-21-4	Undecane	19000
5.	112-40-3	Dodecane	15000
6.	629-50-5	Tridecane	13000
7.	629-59-4	Tetradecane	10000
8.			
9.			
10.			
11.			
12.			
13.			

Values reported for Tentatively Identified Compounds are estimated.

XENCO Laboratories
Trans West Analytical Services, LLC

Certificate of Analytical Results 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id: CL11-2183	**Matrix:** Oil	**Date Received:** Feb-18-11 18:06
Lab Sample Id: 407165-001	**Date Collected:** Feb-17-11 00:00	

Analytical Method: VOCs by EPA 8260B			**Prep Method:** SW5035A
Tech: BLK			**% Moisture:**
Analyst: BLK		**Date Prep:** Feb-21-11 12:35	**Basis:** Wet Weight
Seq Number: 844840			

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Acetone	67-64-1	<1490	1490	mg/kg	02/22/11 14:11	D1	990.1
Benzene	71-43-2	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Bromobenzene	108-86-1	<248	248	mg/kg	02/22/11 14:11	D1	990.1
Bromochloromethane	74-97-5	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Bromodichloromethane	75-27-4	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Bromoform	75-25-2	<99.0	99.0	mg/kg	02/22/11 14:11	D1	990.1
Bromomethane	74-83-9	<495	495	mg/kg	02/22/11 14:11	D1	990.1
2-Butanone	78-93-3	<495	495	mg/kg	02/22/11 14:11	D1	990.1
tert-Butylbenzene	98-06-6	<248	248	mg/kg	02/22/11 14:11	D1	990.1
Sec-Butylbenzene	135-98-8	**520**	248	mg/kg	02/22/11 14:11	D2	990.1
n-Butylbenzene	104-51-8	**637**	248	mg/kg	02/22/11 14:11	D2	990.1
Carbon Disulfide	75-15-0	<495	495	mg/kg	02/22/11 14:11	D1	990.1
Carbon Tetrachloride	56-23-5	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Chlorobenzene	108-90-7	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Chloroethane	75-00-3	<495	495	mg/kg	02/22/11 14:11	D1	990.1
Chloroform	67-66-3	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Chloromethane	74-87-3	<495	495	mg/kg	02/22/11 14:11	D1	990.1
2-Chlorotoluene	95-49-8	<248	248	mg/kg	02/22/11 14:11	D1	990.1
4-Chlorotoluene	106-43-4	<248	248	mg/kg	02/22/11 14:11	D1	990.1
p-Cymene (p-Isopropyltoluene)	99-87-6	**378**	248	mg/kg	02/22/11 14:11	D2	990.1
1,2-Dibromo-3-Chloropropane	96-12-8	<495	495	mg/kg	02/22/11 14:11	D1	990.1
Dibromochloromethane	124-48-1	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
1,2-Dibromoethane	106-93-4	<495	495	mg/kg	02/22/11 14:11	D1	990.1
Dibromomethane	74-95-3	<248	248	mg/kg	02/22/11 14:11	D1	990.1
1,2-Dichlorobenzene	95-50-1	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
1,3-Dichlorobenzene	541-73-1	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
1,4-Dichlorobenzene	106-46-7	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Dichlorodifluoromethane	75-71-8	<495	495	mg/kg	02/22/11 14:11	D1	990.1
1,2-Dichloroethane	107-06-2	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
1,1-Dichloroethane	75-34-3	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
trans-1,2-dichloroethene	156-60-5	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
cis-1,2-Dichloroethene	156-59-2	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
1,1-Dichloroethene	75-35-4	<99.0	99.0	mg/kg	02/22/11 14:11	D1	990.1
2,2-Dichloropropane	594-20-7	<248	248	mg/kg	02/22/11 14:11	D1	990.1
1,3-Dichloropropane	142-28-9	<248	248	mg/kg	02/22/11 14:11	D1	990.1
1,2-Dichloropropane	78-87-5	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
trans-1,3-dichloropropene	10061-02-6	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
1,1-Dichloropropene	563-58-6	<248	248	mg/kg	02/22/11 14:11	D1	990.1
cis-1,3-Dichloropropene	10061-01-5	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Ethylbenzene	100-41-4	**590**	99.0	mg/kg	02/22/11 14:11	D2	990.1

Project: Phoenix XENCO - Master Project

Certificate of Analytical Results 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id: CL11-2183	**Matrix:** Oil	**Date Received:** Feb-18-11 18:06
Lab Sample Id: 407165-001	**Date Collected:** Feb-17-11 00:00	

Analytical Method: VOCs by EPA 8260B		**Prep Method:** SW5035A	
Tech: BLK		**% Moisture:**	
Analyst: BLK	**Date Prep:** Feb-21-11 12:35	**Basis:** Wet Weight	
Seq Number: 844840			

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Hexachlorobutadiene	87-68-3	<495	495	mg/kg	02/22/11 14:11	D1	990.1
2-Hexanone	591-78-6	<495	495	mg/kg	02/22/11 14:11	D1	990.1
Iodomethane (Methyl Iodide)	74-88-4	<495	495	mg/kg	02/22/11 14:11	D1	990.1
Isopropylbenzene	98-82-8	<248	248	mg/kg	02/22/11 14:11	D1	990.1
Naphthalene	91-20-3	**516**	248	mg/kg	02/22/11 14:11	D2	990.1
Methylene Chloride	75-09-2	<495	495	mg/kg	02/22/11 14:11	D1	990.1
4-Methyl-2-Pentanone	108-10-1	<495	495	mg/kg	02/22/11 14:11	D1	990.1
MTBE	1634-04-4	<248	248	mg/kg	02/22/11 14:11	D1	990.1
n-Propylbenzene	103-65-1	**667**	248	mg/kg	02/22/11 14:11	D2	990.1
Styrene	100-42-5	<248	248	mg/kg	02/22/11 14:11	D1	990.1
1,1,1,2-Tetrachloroethane	630-20-6	<248	248	mg/kg	02/22/11 14:11	D1	990.1
1,1,2,2-Tetrachloroethane	79-34-5	<99.0	99.0	mg/kg	02/22/11 14:11	D1	990.1
Tetrachloroethylene	127-18-4	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Toluene	108-88-3	**538**	99.0	mg/kg	02/22/11 14:11	D2	990.1
1,2,4-Trichlorobenzene	120-82-1	<248	248	mg/kg	02/22/11 14:11	D1	990.1
1,2,3-Trichlorobenzene	87-61-6	<248	248	mg/kg	02/22/11 14:11	D1	990.1
1,1,2-Trichloroethane	79-00-5	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
1,1,1-Trichloroethane	71-55-6	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Trichloroethene	79-01-6	<49.5	49.5	mg/kg	02/22/11 14:11	D1	990.1
Trichlorofluoromethane	75-69-4	<495	495	mg/kg	02/22/11 14:11	D1	990.1
1,2,3-Trichloropropane	96-18-4	<248	248	mg/kg	02/22/11 14:11	D1	990.1
1,2,4-Trimethylbenzene	95-63-6	**4070**	248	mg/kg	02/22/11 14:11	D2	990.1
1,3,5-Trimethylbenzene	108-67-8	**930**	248	mg/kg	02/22/11 14:11	D2	990.1
Vinyl Acetate	108-05-4	<495	495	mg/kg	02/22/11 14:11	D1	990.1
Vinyl Chloride	75-01-4	<495	495	mg/kg	02/22/11 14:11	D1	990.1
o-Xylene	95-47-6	**994**	49.5	mg/kg	02/22/11 14:11	D2	990.1
m,p-Xylenes	179601-23-1	**1880**	99.0	mg/kg	02/22/11 14:11	D2	990.1
Total Xylenes	1330-20-7	**2870**	49.5	mg/kg	02/22/11 14:11	D2	990.1

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
4-Bromofluorobenzene	460-00-4	0	%	62-123	02/22/11 14:11	S8
Dibromofluoromethane	1868-53-7	0	%	52-140	02/22/11 14:11	S8
1,2-Dichloroethane-D4	17060-07-0	0	%	54-133	02/22/11 14:11	S8
Toluene-D8	2037-26-5	0	%	63-126	02/22/11 14:11	S8

TENTATIVELY IDENTIFIED COMPOUNDS
EPA METHOD 8260B

CLIENT:	**Southwest Research Institute**	**Client Sample ID:**	CL11-2183
Work Order:	407165	**Collection Date:**	2/17/2011
LAB ID:	407165-01A	**Matrix:**	Jet Fuel
Project Name:		**Date Prepared:**	2/21/2011
Project Number:	1.08.07.13.16246.05	**Date Analyzed:**	2/22/2011

No.	CAS #	Compound Name	Amount (mg/Kg)
1.	8031-33-2	Heptane	1800
2.	589-81-1	3-methylHeptane	4600
3.	2216-30-0	2,5-dimethylHeptane	2200
4.	1678-91-7	ethylCyclohexane	1650
5.	17453-93-9	5-methylDodecane	9200
6.	2216-33-3	3-methylOctane	5700
7.	5911-04-6	3-methylNonane	2500
8.	68608-82-2	1,2-diethylBenzene	5450
9.	934-80-5	4-ethyl-1,2-dimethylBenzene	1900
10.			
11.			
12.			
13.			

Values reported for Tentatively Identified Compounds are estimated.

Certificate of Analytical Results 407165

XENCO Laboratories
Trans West Analytical Services, LLC

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id: CL11-2185	**Matrix:** Oil	**Date Received:** Feb-18-11 18:06
Lab Sample Id: 407165-002	**Date Collected:** Feb-17-11 00:00	

Analytical Method: SVOCs by SW846 8270		**Prep Method:** SW3580A
Tech: CBV		**% Moisture:**
Analyst: JIH	**Date Prep:** Feb-22-11 12:00	
Seq Number: 845089		

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Acenaphthene	83-32-9	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Acenaphthylene	208-96-8	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Anthracene	120-12-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Azobenzene	103-33-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Benzo(a)anthracene	56-55-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Benzo(a)pyrene	50-32-8	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Benzo(b)fluoranthene	205-99-2	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Benzo(g,h,i)perylene	191-24-2	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Benzo(k)fluoranthene	207-08-9	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Benzoic Acid	65-85-0	<4000	4000	mg/kg	02/23/11 22:20	D1	20
Benzyl Alcohol	100-51-6	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Benzyl Butyl Phthalate	85-68-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20
bis(2-chloroethoxy) methane	111-91-1	<1320	1320	mg/kg	02/23/11 22:20	D1	20
bis(2-chloroethyl) ether	111-44-4	<1320	1320	mg/kg	02/23/11 22:20	D1	20
bis(2-chloroisopropyl) ether	108-60-1	<1320	1320	mg/kg	02/23/11 22:20	D1	20
bis(2-ethylhexyl) phthalate	117-81-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20
4-Bromophenyl-phenylether	101-55-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
di-n-Butyl Phthalate	84-74-2	<1320	1320	mg/kg	02/23/11 22:20	D1	20
4-chloro-3-methylphenol	59-50-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20
4-Chloroaniline	106-47-8	<4000	4000	mg/kg	02/23/11 22:20	D1	20
2-Chloronaphthalene	91-58-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20
2-Chlorophenol	95-57-8	<1320	1320	mg/kg	02/23/11 22:20	D1	20
4-Chlorophenyl Phenyl Ether	7005-72-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Chrysene	218-01-9	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Dibenz(a,h)anthracene	53-70-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Dibenzofuran	132-64-9	<1320	1320	mg/kg	02/23/11 22:20	D1	20
1,2-Dichlorobenzene	95-50-1	<1320	1320	mg/kg	02/23/11 22:20	D1	20
1,3-Dichlorobenzene	541-73-1	<1320	1320	mg/kg	02/23/11 22:20	D1	20
1,4-Dichlorobenzene	106-46-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20
3,3-Dichlorobenzidine	91-94-1	<6800	6800	mg/kg	02/23/11 22:20	D1	20
2,4-Dichlorophenol	120-83-2	<2000	2000	mg/kg	02/23/11 22:20	D1	20
Diethyl Phthalate	84-66-2	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Dimethyl Phthalate	131-11-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
2,4-Dimethylphenol	105-67-9	<1320	1320	mg/kg	02/23/11 22:20	D1	20
4,6-dinitro-2-methyl phenol	534-52-1	<8000	8000	mg/kg	02/23/11 22:20	D1	20
2,4-Dinitrophenol	51-28-5	<8000	8000	mg/kg	02/23/11 22:20	D1	20
2,4-Dinitrotoluene	121-14-2	<1320	1320	mg/kg	02/23/11 22:20	D1	20
2,6-Dinitrotoluene	606-20-2	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Fluoranthene	206-44-0	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Fluorene	86-73-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20

Project: Phoenix XENCO - Master Project

Certificate of Analytical Results 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id: CL11-2185	**Matrix:** Oil	**Date Received:** Feb-18-11 18:06
Lab Sample Id: 407165-002	**Date Collected:** Feb-17-11 00:00	

Analytical Method: SVOCs by SW846 8270 — **Prep Method:** SW3580A

Tech: CBV — **% Moisture:**

Analyst: JIH — **Date Prep:** Feb-22-11 12:00

Seq Number: 845089

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Hexachlorobenzene	118-74-1	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Hexachlorobutadiene	87-68-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Hexachlorocyclopentadiene	77-47-4	<8000	8000	mg/kg	02/23/11 22:20	D1	20
Hexachloroethane	67-72-1	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Indeno(1,2,3-c,d)Pyrene	193-39-5	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Isophorone	78-59-1	<1320	1320	mg/kg	02/23/11 22:20	D1	20
2-Methylnaphthalene	91-57-6	<1320	1320	mg/kg	02/23/11 22:20	D1	20
2-methylphenol	95-48-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Naphthalene	91-20-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Nitrobenzene	98-95-3	<1320	1320	mg/kg	02/23/11 22:20	D1	20
2-Nitrophenol	88-75-5	<1320	1320	mg/kg	02/23/11 22:20	D1	20
4-Nitrophenol	100-02-7	<8000	8000	mg/kg	02/23/11 22:20	D1	20
N-Nitrosodi-n-Propylamine	621-64-7	<1320	1320	mg/kg	02/23/11 22:20	D1	20
N-Nitrosodiphenylamine	86-30-6	<1320	1320	mg/kg	02/23/11 22:20	D1	20
di-n-Octyl Phthalate	117-84-0	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Pentachlorophenol	87-86-5	<2680	2680	mg/kg	02/23/11 22:20	D1	20
Phenanthrene	85-01-8	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Phenol	108-95-2	<1320	1320	mg/kg	02/23/11 22:20	D1	20
Pyrene	129-00-0	<1320	1320	mg/kg	02/23/11 22:20	D1	20
1,2,4-Trichlorobenzene	120-82-1	<2000	2000	mg/kg	02/23/11 22:20	D1	20
2,4,6-Trichlorophenol	88-06-2	<4000	4000	mg/kg	02/23/11 22:20	D1	20

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
2-Fluorobiphenyl	321-60-8	0	%	70-130	02/23/11 22:20	S8
2-Fluorophenol	367-12-4	0	%	70-130	02/23/11 22:20	S8
Nitrobenzene-d5	4165-60-0	0	%	70-130	02/23/11 22:20	S8
Phenol-d6	13127-88-3	0	%	70-130	02/23/11 22:20	S8
Terphenyl-D14	1718-51-0	0	%	70-130	02/23/11 22:20	S8
2,4,6-Tribromophenol	118-79-6	0	%	70-130	02/23/11 22:20	S8
2-Chlorophenol-D4	93951-73-6	0	%	70-130	02/23/11 22:20	S8
1,2-Dichlorobenzene-D4	2199-69-1	0	%	70-130	02/23/11 22:20	S8

TENTATIVELY IDENTIFIED COMPOUNDS
EPA METHOD 8270C

CLIENT:	**Southwest Research Institute**	**Client Sample ID:**	CL11-2185
Work Order:	407165	**Collection Date:**	2/17/2011
LAB ID:	407165-02A	**Matrix:**	Jet Fuel
Project Name:		**Date Prepared:**	2/17/2011
Project Number:	1.08.07.13.16246.05	**Date Analyzed:**	2/17/2011

No.	CAS #	Compound Name	Amount (mg/Kg)
1.	111-65-9	Octane	8800
2.	111-84-2	Nonane	12000
3.	124-18-5	Decane	9900
4.	1120-21-4	Undecane	10000
5.	112-40-3	Dodecane	11000
6.	629-50-5	Tridecane	12000
7.	629-59-4	Tetradecane	6000
8.			
9.			
10.			
11.			
12.			
13.			

Values reported for Tentatively Identified Compounds are estimated.

XENCO Laboratories
Trans West Analytical Services, LLC

Certificate of Analytical Results 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id: CL11-2185 **Matrix:** Oil **Date Received:** Feb-18-11 18:06
Lab Sample Id: 407165-002 **Date Collected:** Feb-17-11 00:00

Analytical Method: VOCs by EPA 8260B **Prep Method:** SW5035A
Tech: BLK **% Moisture:**
Analyst: BLK **Date Prep:** Feb-21-11 12:37 **Basis:** Wet Weight
Seq Number: 844840

Dilution Analysis:
Seq#: 844840 Date Analyzed: 02/22/11 15:05 Date Prep: 02/21/11 12:37

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
Acetone	67-64-1	<147	147	mg/kg	02/22/11 15:31	D1	98.04
Benzene	71-43-2	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Bromobenzene	108-86-1	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
Bromochloromethane	74-97-5	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Bromodichloromethane	75-27-4	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Bromoform	75-25-2	<9.80	9.80	mg/kg	02/22/11 15:31	D1	98.04
Bromomethane	74-83-9	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
2-Butanone	78-93-3	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
tert-Butylbenzene	98-06-6	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
Sec-Butylbenzene	135-98-8	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
n-Butylbenzene	104-51-8	**96.4**	24.5	mg/kg	02/22/11 15:31	D2	98.04
Carbon Disulfide	75-15-0	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
Carbon Tetrachloride	56-23-5	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Chlorobenzene	108-90-7	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Chloroethane	75-00-3	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
Chloroform	67-66-3	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Chloromethane	74-87-3	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
2-Chlorotoluene	95-49-8	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
4-Chlorotoluene	106-43-4	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
p-Cymene (p-Isopropyltoluene)	99-87-6	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,2-Dibromo-3-Chloropropane	96-12-8	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
Dibromochloromethane	124-48-1	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
1,2-Dibromoethane	106-93-4	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
Dibromomethane	74-95-3	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,2-Dichlorobenzene	95-50-1	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
1,3-Dichlorobenzene	541-73-1	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
1,4-Dichlorobenzene	106-46-7	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Dichlorodifluoromethane	75-71-8	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
1,2-Dichloroethane	107-06-2	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
1,1-Dichloroethane	75-34-3	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
trans-1,2-dichloroethene	156-60-5	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
cis-1,2-Dichloroethene	156-59-2	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
1,1-Dichloroethene	75-35-4	<9.80	9.80	mg/kg	02/22/11 15:31	D1	98.04
2,2-Dichloropropane	594-20-7	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,3-Dichloropropane	142-28-9	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,2-Dichloropropane	78-87-5	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
trans-1,3-dichloropropene	10061-02-6	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04

XENCO Laboratories
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Certificate of Analytical Results 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Sample Id: CL11-2185 **Matrix:** Oil **Date Received:** Feb-18-11 18:06
Lab Sample Id: 407165-002 **Date Collected:** Feb-17-11 00:00

Analytical Method: VOCs by EPA 8260B **Prep Method:** SW5035A
Tech: BLK **% Moisture:**
Analyst: BLK **Date Prep:** Feb-21-11 12:37 **Basis:** Wet Weight
Seq Number: 844840

Parameter	Cas Number	Result	RL	Units	Analysis Date	Flag	Dil
1,1-Dichloropropene	563-58-6	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
cis-1,3-Dichloropropene	10061-01-5	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Ethylbenzene	100-41-4	**120**	9.80	mg/kg	02/22/11 15:31	D2	98.04
Hexachlorobutadiene	87-68-3	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
2-Hexanone	591-78-6	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
Iodomethane (Methyl Iodide)	74-88-4	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
Isopropylbenzene	98-82-8	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
Naphthalene	91-20-3	**24.8**	24.5	mg/kg	02/22/11 15:31	D2	98.04
Methylene Chloride	75-09-2	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
4-Methyl-2-Pentanone	108-10-1	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
MTBE	1634-04-4	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
n-Propylbenzene	103-65-1	**88.5**	24.5	mg/kg	02/22/11 15:31	D2	98.04
Styrene	100-42-5	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,1,1,2-Tetrachloroethane	630-20-6	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,1,2,2-Tetrachloroethane	79-34-5	<9.80	9.80	mg/kg	02/22/11 15:31	D1	98.04
Tetrachloroethylene	127-18-4	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Toluene	108-88-3	<9.80	9.80	mg/kg	02/22/11 15:31	D1	98.04
1,2,4-Trichlorobenzene	120-82-1	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,2,3-Trichlorobenzene	87-61-6	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,1,2-Trichloroethane	79-00-5	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
1,1,1-Trichloroethane	71-55-6	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Trichloroethene	79-01-6	<4.90	4.90	mg/kg	02/22/11 15:31	D1	98.04
Trichlorofluoromethane	75-69-4	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
1,2,3-Trichloropropane	96-18-4	<24.5	24.5	mg/kg	02/22/11 15:31	D1	98.04
1,2,4-Trimethylbenzene	95-63-6	**1220**	245	mg/kg	02/22/11 15:05	D2	980.39
1,3,5-Trimethylbenzene	108-67-8	**298**	24.5	mg/kg	02/22/11 15:31	D2	98.04
Vinyl Acetate	108-05-4	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
Vinyl Chloride	75-01-4	<49.0	49.0	mg/kg	02/22/11 15:31	D1	98.04
o-Xylene	95-47-6	**339**	4.90	mg/kg	02/22/11 15:31	D2	98.04
m,p-Xylenes	179601-23-1	**971**	9.80	mg/kg	02/22/11 15:31	D2	98.04
Total Xylenes	1330-20-7	**1310**	4.90	mg/kg	02/22/11 15:31	D2	98.04

Surrogate	Cas Number	% Recovery	Units	Limits	Analysis Date	Flag
4-Bromofluorobenzene	460-00-4	200	%	62-123	02/22/11 15:31	S10
Dibromofluoromethane	1868-53-7	99	%	52-140	02/22/11 15:31	
1,2-Dichloroethane-D4	17060-07-0	99	%	54-133	02/22/11 15:31	
Toluene-D8	2037-26-5	200	%	63-126	02/22/11 15:31	S10

TENTATIVELY IDENTIFIED COMPOUNDS
EPA METHOD 8260B

CLIENT:	**Southwest Research Institute**	**Client Sample ID:**	CL11-2185
Work Order:	407165	**Collection Date:**	2/17/2011
LAB ID:	407165-02A	**Matrix:**	Jet Fuel
Project Name:		**Date Prepared:**	2/21/2011
Project Number:	1.08.07.13.16246.05	**Date Analyzed:**	2/22/2011

No.	CAS #	Compound Name	Amount (mg/Kg)
1.	17453-93-9	5-methylDodecane	24000
2.	1632-70-8	6-methylUndecane	15500
3.	61193-19-9	Nonane	15000
4.	15869-89-3	2,5-dimethylOctane	7500
5.	15869-93-9	3,5-dimethylOctane	27500
6.	5911-04-6	3-methylNonane	12500
7.	73138-29-1	Decane	9000
8.	3891-98-3	2,6,10-trimethylDodecane	8000
9.	61193-21-3	Undecane	8500
10.	94094-93-6	Dodecane	7500
11.			
12.			
13.			

Values reported for Tentatively Identified Compounds are estimated.

XENCO Laboratories
Trans West Analytical Services, LLC

Surrogate Recoveries

Project Name: **Phoenix XENCO - Master Project**

Work Orders : 407165,

Project ID: 1.08.07.13.16246.05

Method: **VOCs by EPA 8260B** **Matrix:** Solid **Prep Method:** SW5035A
Sample: 596110-1-BLK **Seq Number:** 844840 **Prep Date:** 02/21/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
4-Bromofluorobenzene	97	62-123	%	02/22/2011 10:23	
Dibromofluoromethane	92	52-140	%	02/22/2011 10:23	
1,2-Dichloroethane-D4	92	54-133	%	02/22/2011 10:23	
Toluene-D8	96	63-126	%	02/22/2011 10:23	

Method: **VOCs by EPA 8260B** **Matrix:** Solid **Prep Method:** SW5035A
Sample: 596110-1-BKS **Seq Number:** 844840 **Prep Date:** 02/21/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
4-Bromofluorobenzene	102	62-123	%	02/22/2011 10:49	
Dibromofluoromethane	103	52-140	%	02/22/2011 10:49	
1,2-Dichloroethane-D4	97	54-133	%	02/22/2011 10:49	
Toluene-D8	98	63-126	%	02/22/2011 10:49	

Method: **VOCs by EPA 8260B** **Matrix:** Solid **Prep Method:** SW5035A
Sample: 596110-1-BSD **Seq Number:** 844840 **Prep Date:** 02/21/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
4-Bromofluorobenzene	97	62-123	%	02/22/2011 11:29	
Dibromofluoromethane	94	52-140	%	02/22/2011 11:29	
1,2-Dichloroethane-D4	92	54-133	%	02/22/2011 11:29	
Toluene-D8	93	63-126	%	02/22/2011 11:29	

Method: **VOCs by EPA 8260B** **Matrix:** Soil **Prep Method:** SW5035A
Sample: 406782-003 S **Seq Number:** 844840 **Prep Date:** 02/21/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
4-Bromofluorobenzene	107	62-123	%	02/22/2011 13:18	
Dibromofluoromethane	110	52-140	%	02/22/2011 13:18	
1,2-Dichloroethane-D4	107	54-133	%	02/22/2011 13:18	
Toluene-D8	105	63-126	%	02/22/2011 13:18	

Method: **VOCs by EPA 8260B** **Matrix:** Soil **Prep Method:** SW5035A
Sample: 406782-003 SD **Seq Number:** 844840 **Prep Date:** 02/21/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
4-Bromofluorobenzene	100	62-123	%	02/22/2011 13:45	
Dibromofluoromethane	107	52-140	%	02/22/2011 13:45	
1,2-Dichloroethane-D4	101	54-133	%	02/22/2011 13:45	
Toluene-D8	99	63-126	%	02/22/2011 13:45	

XENCO Laboratories
Trans West Analytical Services, LLC

Surrogate Recoveries

Project Name: Phoenix XENCO - Master Project

Work Orders : 407165,

Project ID: 1.08.07.13.16246.05

Method: SVOCs by SW846 8270 **Matrix:** Oil **Prep Method:** SW3580A

Sample: 596200-1-BLK **Seq Number:** 845089 **Prep Date:** 02/22/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
2-Fluorobiphenyl	105	70-130	%	02/23/2011 13:46	
2-Fluorophenol	103	70-130	%	02/23/2011 13:46	
Nitrobenzene-d5	101	70-130	%	02/23/2011 13:46	
Phenol-d6	100	70-130	%	02/23/2011 13:46	
Terphenyl-D14	108	70-130	%	02/23/2011 13:46	
2,4,6-Tribromophenol	47	70-130	%	02/23/2011 13:46	N1
2-Chlorophenol-D4	103	70-130	%	02/23/2011 13:46	
1,2-Dichlorobenzene-D4	106	70-130	%	02/23/2011 13:46	

Method: SVOCs by SW846 8270 **Matrix:** Oil **Prep Method:** SW3580A

Sample: 596200-1-BKS **Seq Number:** 845089 **Prep Date:** 02/22/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
2-Fluorobiphenyl	104	70-130	%	02/23/2011 14:31	
2-Fluorophenol	102	70-130	%	02/23/2011 14:31	
Nitrobenzene-d5	100	70-130	%	02/23/2011 14:31	
Phenol-d6	99	70-130	%	02/23/2011 14:31	
Terphenyl-D14	106	70-130	%	02/23/2011 14:31	
2,4,6-Tribromophenol	87	70-130	%	02/23/2011 14:31	
2-Chlorophenol-D4	103	70-130	%	02/23/2011 14:31	
1,2-Dichlorobenzene-D4	104	70-130	%	02/23/2011 14:31	

Method: SVOCs by SW846 8270 **Matrix:** Oil **Prep Method:** SW3580A

Sample: 596200-1-BSD **Seq Number:** 845089 **Prep Date:** 02/22/2011

Surrogate	% Rec	Limits	Units	Analysis Date	Flag
2-Fluorobiphenyl	112	70-130	%	02/23/2011 15:16	
2-Fluorophenol	110	70-130	%	02/23/2011 15:16	
Nitrobenzene-d5	109	70-130	%	02/23/2011 15:16	
Phenol-d6	106	70-130	%	02/23/2011 15:16	
Terphenyl-D14	112	70-130	%	02/23/2011 15:16	
2,4,6-Tribromophenol	94	70-130	%	02/23/2011 15:16	
2-Chlorophenol-D4	110	70-130	%	02/23/2011 15:16	
1,2-Dichlorobenzene-D4	110	70-130	%	02/23/2011 15:16	

XENCO Laboratories
Trans West Analytical Services, LLC

QC Summary 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Analytical Method: SVOCs by SW846 8270 Prep Method: SW3580A
Seq Number: 845089 Matrix: Oil Date Prep: 02/22/2011
MB Sample Id: 596200-1-BLK LCS Sample Id: 596200-1-BKS LCSD Sample Id: 596200-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Acenaphthene	<66.0	200	205	103	219	110	70-130	7	30	mg/kg	02/23/11 14:31	N1
Acenaphthylene	<66.0	200	206	103	222	111	70-130	7	30	mg/kg	02/23/11 14:31	N1
Anthracene	<66.0	200	198	99	211	106	70-130	6	30	mg/kg	02/23/11 14:31	N1
Azobenzene	<66.0	200	212	106	228	114	70-130	7	30	mg/kg	02/23/11 14:31	N1
Benzo(a)anthracene	<66.0	200	203	102	212	106	70-130	4	30	mg/kg	02/23/11 14:31	N1
Benzo(a)pyrene	<66.0	200	198	99	209	105	70-130	5	30	mg/kg	02/23/11 14:31	N1
Benzo(b)fluoranthene	<66.0	200	196	98	206	103	70-130	5	30	mg/kg	02/23/11 14:31	N1
Benzo(g,h,i)perylene	<66.0	200	203	102	207	104	70-130	2	30	mg/kg	02/23/11 14:31	N1
Benzo(k)fluoranthene	<66.0	200	208	104	221	111	70-130	6	30	mg/kg	02/23/11 14:31	N1
Benzoic Acid	<180	400	255	64	304	76	70-130	18	30	mg/kg	02/23/11 14:31	N1
Benzyl Alcohol	<66.0	200	179	90	190	95	70-130	6	30	mg/kg	02/23/11 14:31	N1
Benzyl Butyl Phthalate	<66.0	200	216	108	223	112	70-130	3	30	mg/kg	02/23/11 14:31	N1
bis(2-chloroethoxy) methane	<66.0	200	198	99	213	107	70-130	7	30	mg/kg	02/23/11 14:31	N1
bis(2-chloroethyl) ether	<66.0	200	209	105	224	112	70-130	7	30	mg/kg	02/23/11 14:31	N1
bis(2-chloroisopropyl) ether	<66.0	200	212	106	221	111	70-130	4	30	mg/kg	02/23/11 14:31	N1
bis(2-ethylhexyl) phthalate	<66.0	200	226	113	231	116	70-130	2	30	mg/kg	02/23/11 14:31	N1
4-Bromophenyl-phenylether	<66.0	200	206	103	222	111	70-130	7	30	mg/kg	02/23/11 14:31	N1
di-n-Butyl Phthalate	<66.0	200	215	108	227	114	70-130	5	30	mg/kg	02/23/11 14:31	N1
4-chloro-3-methylphenol	<66.0	400	382	96	409	102	70-130	7	30	mg/kg	02/23/11 14:31	N1
4-Chloroaniline	<66.0	200	161	81	140	70	70-130	14	30	mg/kg	02/23/11 14:31	N1
2-Chloronaphthalene	<66.0	200	205	103	222	111	70-130	8	30	mg/kg	02/23/11 14:31	N1
2-Chlorophenol	<66.0	400	420	105	448	112	70-130	6	30	mg/kg	02/23/11 14:31	N1
4-Chlorophenyl Phenyl Ether	<66.0	200	210	105	224	112	70-130	6	30	mg/kg	02/23/11 14:31	N1
Chrysene	<66.0	200	206	103	216	108	70-130	5	30	mg/kg	02/23/11 14:31	N1
Dibenz(a,h)anthracene	<66.0	200	205	103	212	106	70-130	3	30	mg/kg	02/23/11 14:31	N1
Dibenzofuran	<66.0	200	204	102	220	110	70-130	8	30	mg/kg	02/23/11 14:31	N1
1,2-Dichlorobenzene	<66.0	200	207	104	219	110	70-130	6	30	mg/kg	02/23/11 14:31	N1
1,3-Dichlorobenzene	<66.0	200	211	106	223	112	70-130	6	30	mg/kg	02/23/11 14:31	N1
1,4-Dichlorobenzene	<66.0	200	211	106	225	113	70-130	6	30	mg/kg	02/23/11 14:31	N1
3,3-Dichlorobenzidine	<66.0	200	140	70	152	76	70-130	8	30	mg/kg	02/23/11 14:31	N1
2,4-Dichlorophenol	<100	400	394	99	426	107	70-130	8	30	mg/kg	02/23/11 14:31	N1
Diethyl Phthalate	<66.0	200	206	103	217	109	70-130	5	30	mg/kg	02/23/11 14:31	N1
Dimethyl Phthalate	<66.0	200	201	101	216	108	70-130	7	30	mg/kg	02/23/11 14:31	N1
2,4-Dimethylphenol	<66.0	400	384	96	413	103	70-130	7	30	mg/kg	02/23/11 14:31	N1
4,6-dinitro-2-methyl phenol	<100	400	316	79	368	92	70-130	15	30	mg/kg	02/23/11 14:31	N1
2,4-Dinitrophenol	<100	400	253	63	307	77	70-130	19	30	mg/kg	02/23/11 14:31	N1
2,4-Dinitrotoluene	<66.0	200	200	100	213	107	70-130	6	30	mg/kg	02/23/11 14:31	N1
2,6-Dinitrotoluene	<66.0	200	199	100	215	108	70-130	8	30	mg/kg	02/23/11 14:31	N1
Fluoranthene	<66.0	200	208	104	219	110	70-130	5	30	mg/kg	02/23/11 14:31	N1
Fluorene	<66.0	200	206	103	221	111	70-130	7	30	mg/kg	02/23/11 14:31	N1
Hexachlorobenzene	<66.0	200	201	101	216	108	70-130	7	30	mg/kg	02/23/11 14:31	N1
Hexachlorobutadiene	<66.0	200	190	95	204	102	70-130	7	30	mg/kg	02/23/11 14:31	N1
Hexachlorocyclopentadiene	<66.0	200	175	88	207	104	70-130	17	30	mg/kg	02/23/11 14:31	N1
Hexachloroethane	<66.0	200	212	106	224	112	70-130	6	30	mg/kg	02/23/11 14:31	N1
Indeno(1,2,3-c,d)Pyrene	<66.0	200	207	104	213	107	70-130	3	30	mg/kg	02/23/11 14:31	N1
Isophorone	<66.0	200	209	105	223	112	70-130	6	30	mg/kg	02/23/11 14:31	N1

QC Summary 407165

XENCO Laboratories
Trans West Analytical Services, LLC

Southwest Research Institute, San Antonio, TX
Phoenix XENCO - Master Project

Analytical Method: SVOCs by SW846 8270 Prep Method: SW3580A
Seq Number: 845089 Matrix: Oil Date Prep: 02/22/2011
MB Sample Id: 596200-1-BLK LCS Sample Id: 596200-1-BKS LCSD Sample Id: 596200-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
2-Methylnaphthalene	<66.0	200	200	100	215	108	70-130	7	30	mg/kg	02/23/11 14:31	N1
2-methylphenol	<66.0	400	397	99	417	104	70-130	5	30	mg/kg	02/23/11 14:31	N1
Naphthalene	<66.0	200	206	103	222	111	70-130	7	30	mg/kg	02/23/11 14:31	N1
Nitrobenzene	<66.0	200	202	101	219	110	70-130	8	30	mg/kg	02/23/11 14:31	N1
2-Nitrophenol	<66.0	400	370	93	407	102	70-130	10	30	mg/kg	02/23/11 14:31	N1
4-Nitrophenol	<100	400	323	81	364	91	70-130	12	30	mg/kg	02/23/11 14:31	N1
N-Nitrosodi-n-Propylamine	<66.0	200	212	106	221	111	70-130	4	30	mg/kg	02/23/11 14:31	N1
N-Nitrosodiphenylamine	<66.0	200	237	119	253	127	70-130	7	30	mg/kg	02/23/11 14:31	N1
di-n-Octyl Phthalate	<66.0	200	222	111	229	115	70-130	3	30	mg/kg	02/23/11 14:31	N1
Pentachlorophenol	<134	400	289	72	322	81	70-130	11	30	mg/kg	02/23/11 14:31	N1
Phenanthrene	<66.0	200	203	102	217	109	70-130	7	30	mg/kg	02/23/11 14:31	N1
Phenol	<66.0	400	396	99	424	106	70-130	7	30	mg/kg	02/23/11 14:31	N1
Pyrene	<66.0	200	211	106	220	110	70-130	4	30	mg/kg	02/23/11 14:31	N1
1,2,4-Trichlorobenzene	<100	200	223	112	242	121	70-130	8	30	mg/kg	02/23/11 14:31	N1
2,4,6-Trichlorophenol	<200	400	377	94	412	103	70-130	9	30	mg/kg	02/23/11 14:31	N1

QC Summary 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Analytical Method:	**VOCs by EPA 8260B**			Prep Method:	SW5035A
Seq Number:	844840	Matrix:	Solid	Date Prep:	02/21/2011
MB Sample Id:	596110-1-BLK	LCS Sample Id:	596110-1-BKS	LCSD Sample Id:	596110-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Acetone	<1.50	2	2.38	119	2.63	132	52-140	10	23	mg/kg	02/22/11 10:49	
Benzene	<0.0500	1	1.01	101	1.01	101	70-130	0	20	mg/kg	02/22/11 10:49	
Bromobenzene	<0.250	1	1.05	105	1.04	104	70-130	1	20	mg/kg	02/22/11 10:49	
Bromochloromethane	<0.0500	1	1.10	110	1.04	104	70-130	6	20	mg/kg	02/22/11 10:49	
Bromodichloromethane	<0.0500	1	1.04	104	1.02	102	70-130	2	20	mg/kg	02/22/11 10:49	
Bromoform	<0.100	1	1.06	106	0.993	99	64-120	7	20	mg/kg	02/22/11 10:49	
Bromomethane	<0.500	2	1.74	87	1.86	93	21-168	7	56	mg/kg	02/22/11 10:49	
2-Butanone	<0.500	2	2.61	131	2.54	127	70-133	3	23	mg/kg	02/22/11 10:49	
tert-Butylbenzene	<0.250	1	1.08	108	1.04	104	70-130	4	20	mg/kg	02/22/11 10:49	
Sec-Butylbenzene	<0.250	1	1.10	110	1.05	105	70-130	5	20	mg/kg	02/22/11 10:49	
n-Butylbenzene	<0.250	1	1.10	110	1.06	106	70-130	4	20	mg/kg	02/22/11 10:49	
Carbon Disulfide	<0.500	2	2.44	122	2.80	140	43-164	14	38	mg/kg	02/22/11 10:49	
Carbon Tetrachloride	<0.0500	1	0.979	98	0.999	100	70-130	2	20	mg/kg	02/22/11 10:49	
Chlorobenzene	<0.0500	1	1.07	107	1.04	104	70-130	3	20	mg/kg	02/22/11 10:49	
Chloroethane	<0.500	2	1.43	72	1.94	97	35-156	30	48	mg/kg	02/22/11 10:49	
Chloroform	<0.0500	1	1.10	110	1.06	106	70-130	4	20	mg/kg	02/22/11 10:49	
Chloromethane	<0.500	2	2.17	109	2.11	106	36-153	3	41	mg/kg	02/22/11 10:49	
2-Chlorotoluene	<0.250	1	1.10	110	1.08	108	70-130	2	20	mg/kg	02/22/11 10:49	
4-Chlorotoluene	<0.250	1	1.11	111	1.08	108	70-130	3	20	mg/kg	02/22/11 10:49	
p-Cymene (p-Isopropyltoluene)	<0.250	1	1.12	112	1.08	108	70-130	4	20	mg/kg	02/22/11 10:49	
1,2-Dibromo-3-Chloropropane	<0.500	1	1.10	110	0.990	99	64-114	11	20	mg/kg	02/22/11 10:49	
Dibromochloromethane	<0.0500	1	1.04	104	1.00	100	70-130	4	20	mg/kg	02/22/11 10:49	
1,2-Dibromoethane	<0.500	1	1.10	110	1.03	103	70-130	7	20	mg/kg	02/22/11 10:49	
Dibromomethane	<0.250	1	1.09	109	1.02	102	70-130	7	20	mg/kg	02/22/11 10:49	
1,2-Dichlorobenzene	<0.0500	1	1.07	107	1.07	107	70-130	0	20	mg/kg	02/22/11 10:49	
1,3-Dichlorobenzene	<0.0500	1	1.06	106	1.03	103	70-130	3	20	mg/kg	02/22/11 10:49	
1,4-Dichlorobenzene	<0.0500	1	1.04	104	1.04	104	70-130	0	20	mg/kg	02/22/11 10:49	
Dichlorodifluoromethane	<0.500	2	1.95	98	1.92	96	12-169	2	49	mg/kg	02/22/11 10:49	
1,2-Dichloroethane	<0.0500	1	1.05	105	1.04	104	70-130	1	20	mg/kg	02/22/11 10:49	
1,1-Dichloroethane	<0.0500	1	1.11	111	1.06	106	70-130	5	20	mg/kg	02/22/11 10:49	
trans-1,2-dichloroethene	<0.0500	1	1.11	111	1.09	109	70-130	2	20	mg/kg	02/22/11 10:49	
cis-1,2-Dichloroethene	<0.0500	1	1.11	111	1.05	105	70-130	6	20	mg/kg	02/22/11 10:49	
1,1-Dichloroethene	<0.100	1	1.10	110	1.08	108	59-126	2	21	mg/kg	02/22/11 10:49	
2,2-Dichloropropane	<0.250	1	1.06	106	1.06	106	64-123	0	20	mg/kg	02/22/11 10:49	
1,3-Dichloropropane	<0.250	1	1.07	107	1.03	103	70-130	4	20	mg/kg	02/22/11 10:49	
1,2-Dichloropropane	<0.0500	1	1.02	102	1.01	101	70-130	1	20	mg/kg	02/22/11 10:49	
trans-1,3-dichloropropene	<0.0500	1	1.19	119	1.15	115	70-130	3	20	mg/kg	02/22/11 10:49	
1,1-Dichloropropene	<0.250	1	1.03	103	1.04	104	70-130	1	20	mg/kg	02/22/11 10:49	
cis-1,3-Dichloropropene	<0.0500	1	1.07	107	1.03	103	70-130	4	20	mg/kg	02/22/11 10:49	
Ethylbenzene	<0.100	1	1.09	109	1.06	106	70-130	3	20	mg/kg	02/22/11 10:49	
Hexachlorobutadiene	<0.500	1	1.08	108	1.01	101	70-130	7	20	mg/kg	02/22/11 10:49	
2-Hexanone	<0.500	2	2.52	126	2.26	113	70-130	11	20	mg/kg	02/22/11 10:49	
Iodomethane (Methyl Iodide)	<0.500	2	2.28	114	1.91	96	53-157	18	31	mg/kg	02/22/11 10:49	
Isopropylbenzene	<0.250	1	1.15	115	1.11	111	70-130	4	20	mg/kg	02/22/11 10:49	
Naphthalene	<0.250	1	1.12	112	1.09	109	70-130	3	20	mg/kg	02/22/11 10:49	
Methylene Chloride	<0.500	1	1.05	105	1.07	107	70-130	2	20	mg/kg	02/22/11 10:49	

XENCO Laboratories
Trans West Analytical Services, LLC

QC Summary 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Analytical Method: VOCs by EPA 8260B Prep Method: SW5035A

Seq Number: 844840 Matrix: Solid Date Prep: 02/21/2011

MB Sample Id: 596110-1-BLK LCS Sample Id: 596110-1-BKS LCSD Sample Id: 596110-1-BSD

Parameter	MB Result	Spike Amount	LCS Result	LCS %Rec	LCSD Result	LCSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
4-Methyl-2-Pentanone	<0.500	2	2.44	122	2.25	113	70-130	8	20	mg/kg	02/22/11 10:49	
MTBE	<0.250	2	2.31	116	2.26	113	70-130	2	20	mg/kg	02/22/11 10:49	
n-Propylbenzene	<0.250	1	1.13	113	1.09	109	70-130	4	20	mg/kg	02/22/11 10:49	
Styrene	<0.250	1	1.10	110	1.07	107	70-130	3	20	mg/kg	02/22/11 10:49	
1,1,1,2-Tetrachloroethane	<0.250	1	1.04	104	1.01	101	70-130	3	20	mg/kg	02/22/11 10:49	
1,1,2,2-Tetrachloroethane	<0.100	1	1.18	118	1.08	108	70-130	9	20	mg/kg	02/22/11 10:49	
Tetrachloroethylene	<0.0500	1	1.01	101	0.985	99	70-130	3	20	mg/kg	02/22/11 10:49	
Toluene	<0.100	1	1.04	104	1.02	102	70-130	2	20	mg/kg	02/22/11 10:49	
1,2,4-Trichlorobenzene	<0.250	1	1.06	106	1.05	105	70-130	1	20	mg/kg	02/22/11 10:49	
1,2,3-Trichlorobenzene	<0.250	1	1.03	103	1.05	105	70-130	2	20	mg/kg	02/22/11 10:49	
1,1,2-Trichloroethane	<0.0500	1	1.08	108	1.06	106	70-130	2	20	mg/kg	02/22/11 10:49	
1,1,1-Trichloroethane	<0.0500	1	1.06	106	1.04	104	70-130	2	20	mg/kg	02/22/11 10:49	
Trichloroethene	<0.0500	1	1.01	101	1.00	100	70-130	1	20	mg/kg	02/22/11 10:49	
Trichlorofluoromethane	<0.500	2	1.98	99	1.91	96	54-136	4	34	mg/kg	02/22/11 10:49	
1,2,3-Trichloropropane	<0.250	1	1.13	113	1.01	101	70-130	11	20	mg/kg	02/22/11 10:49	
1,2,4-Trimethylbenzene	<0.250	1	1.13	113	1.09	109	70-130	4	20	mg/kg	02/22/11 10:49	
1,3,5-Trimethylbenzene	<0.250	1	1.12	112	1.07	107	70-130	5	20	mg/kg	02/22/11 10:49	
Vinyl Acetate	<0.500	2	2.76	138	2.67	134	22-183	3	20	mg/kg	02/22/11 10:49	
Vinyl Chloride	<0.500	2	2.33	117	2.20	110	38-154	6	20	mg/kg	02/22/11 10:49	
o-Xylene	<0.0500	1	1.07	107	1.03	103	70-130	4	20	mg/kg	02/22/11 10:49	
m,p-Xylenes	<0.100	2	2.14	107	2.07	104	70-130	3	20	mg/kg	02/22/11 10:49	

XENCO Laboratories
Trans West Analytical Services, LLC

QC Summary 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Analytical Method: VOCs by EPA 8260B Prep Method: SW5035A
Seq Number: 844840 Matrix: Soil Date Prep: 02/21/2011
Parent Sample Id: 406782-003 MS Sample Id: 406782-003 S MSD Sample Id: 406782-003 SD

Parameter	Parent Result	Spike Amount	MS Result	MS %Rec	MSD Result	MSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
Acetone	<1.48	1.98	3.08	156	2.76	139	49-140	11	35	mg/kg	02/22/11 13:18	M1
Benzene	<0.0495	0.989	0.996	101	1.04	105	63-115	4	22	mg/kg	02/22/11 13:18	
Bromobenzene	<0.247	0.989	1.05	106	1.08	109	57-123	3	25	mg/kg	02/22/11 13:18	
Bromochloromethane	<0.0495	0.989	1.07	108	1.13	114	52-126	5	32	mg/kg	02/22/11 13:18	
Bromodichloromethane	<0.0495	0.989	1.05	106	1.09	110	57-120	4	22	mg/kg	02/22/11 13:18	
Bromoform	<0.0989	0.989	0.976	99	1.00	101	53-120	2	24	mg/kg	02/22/11 13:18	
Bromomethane	<0.495	1.98	1.80	91	1.86	94	25-190	3	54	mg/kg	02/22/11 13:18	
2-Butanone	<0.495	1.98	2.72	137	2.73	138	57-137	0	44	mg/kg	02/22/11 13:18	M1
tert-Butylbenzene	<0.247	0.989	1.10	111	1.10	111	49-133	0	28	mg/kg	02/22/11 13:18	
Sec-Butylbenzene	<0.247	0.989	1.11	112	1.11	112	47-137	0	29	mg/kg	02/22/11 13:18	
n-Butylbenzene	<0.247	0.989	1.09	110	1.09	110	35-134	0	30	mg/kg	02/22/11 13:18	
Carbon Disulfide	<0.495	1.98	2.47	125	2.94	148	26-156	17	40	mg/kg	02/22/11 13:18	
Carbon Tetrachloride	<0.0495	0.989	1.03	104	1.02	103	47-127	1	26	mg/kg	02/22/11 13:18	
Chlorobenzene	<0.0495	0.989	1.05	106	1.06	107	63-116	1	22	mg/kg	02/22/11 13:18	
Chloroethane	<0.495	1.98	1.22	62	1.54	78	32-145	23	51	mg/kg	02/22/11 13:18	
Chloroform	<0.0495	0.989	1.12	113	1.15	116	51-124	3	34	mg/kg	02/22/11 13:18	
Chloromethane	<0.495	1.98	2.18	110	2.31	117	28-142	6	48	mg/kg	02/22/11 13:18	
2-Chlorotoluene	<0.247	0.989	1.12	113	1.12	113	62-119	0	26	mg/kg	02/22/11 13:18	
4-Chlorotoluene	<0.247	0.989	1.14	115	1.14	115	65-116	0	24	mg/kg	02/22/11 13:18	
p-Cymene (p-Isopropyltoluene)	<0.247	0.989	1.13	114	1.14	115	44-138	1	28	mg/kg	02/22/11 13:18	
1,2-Dibromo-3-Chloropropane	<0.495	0.989	1.01	102	1.07	108	55-116	6	25	mg/kg	02/22/11 13:18	
Dibromochloromethane	<0.0495	0.989	1.00	101	1.02	103	56-121	2	24	mg/kg	02/22/11 13:18	
1,2-Dibromoethane	<0.495	0.989	1.06	107	1.08	109	58-115	2	22	mg/kg	02/22/11 13:18	
Dibromomethane	<0.247	0.989	1.04	105	1.11	112	59-117	7	23	mg/kg	02/22/11 13:18	
1,2-Dichlorobenzene	<0.0495	0.989	1.07	108	1.09	110	62-117	2	23	mg/kg	02/22/11 13:18	
1,3-Dichlorobenzene	<0.0495	0.989	1.08	109	1.10	111	61-118	2	24	mg/kg	02/22/11 13:18	
1,4-Dichlorobenzene	<0.0495	0.989	1.03	104	1.03	104	64-118	0	23	mg/kg	02/22/11 13:18	
Dichlorodifluoromethane	<0.495	1.98	2.05	104	2.02	102	25-143	1	62	mg/kg	02/22/11 13:18	
1,2-Dichloroethane	<0.0495	0.989	1.09	110	1.13	114	56-122	4	22	mg/kg	02/22/11 13:18	
1,1-Dichloroethane	<0.0495	0.989	1.10	111	1.16	117	50-126	5	36	mg/kg	02/22/11 13:18	
trans-1,2-dichloroethene	<0.0495	0.989	1.11	112	1.16	117	49-127	4	38	mg/kg	02/22/11 13:18	
cis-1,2-Dichloroethene	<0.0495	0.989	1.09	110	1.13	114	46-129	4	37	mg/kg	02/22/11 13:18	
1,1-Dichloroethene	<0.0989	0.989	1.12	113	1.14	115	36-131	2	55	mg/kg	02/22/11 13:18	
2,2-Dichloropropane	<0.247	0.989	1.12	113	1.13	114	41-133	1	32	mg/kg	02/22/11 13:18	
1,3-Dichloropropane	<0.247	0.989	1.06	107	1.08	109	55-117	2	24	mg/kg	02/22/11 13:18	
1,2-Dichloropropane	<0.0495	0.989	1.03	104	1.06	107	64-112	3	21	mg/kg	02/22/11 13:18	
trans-1,3-dichloropropene	<0.0495	0.989	1.17	118	1.17	118	59-127	0	22	mg/kg	02/22/11 13:18	
1,1-Dichloropropene	<0.247	0.989	1.05	106	1.06	107	57-119	1	26	mg/kg	02/22/11 13:18	
cis-1,3-Dichloropropene	<0.0495	0.989	1.07	108	1.11	112	66-115	4	22	mg/kg	02/22/11 13:18	
Ethylbenzene	<0.0989	0.989	1.08	109	1.08	109	59-117	0	27	mg/kg	02/22/11 13:18	
Hexachlorobutadiene	<0.495	0.989	1.02	103	0.969	98	41-148	5	26	mg/kg	02/22/11 13:18	
2-Hexanone	<0.495	1.98	2.31	117	2.30	116	60-128	0	25	mg/kg	02/22/11 13:18	
Iodomethane (Methyl Iodide)	<0.495	1.98	1.89	95	2.10	106	41-151	11	57	mg/kg	02/22/11 13:18	
Isopropylbenzene	<0.247	0.989	1.16	117	1.16	117	58-139	0	29	mg/kg	02/22/11 13:18	
Naphthalene	<0.247	0.989	1.07	108	1.13	114	37-138	5	26	mg/kg	02/22/11 13:18	
Methylene Chloride	<0.495	0.989	1.07	108	1.12	113	48-123	5	37	mg/kg	02/22/11 13:18	

XENCO Laboratories
Trans West Analytical Services, LLC

QC Summary 407165

Southwest Research Institute, San Antonio, TX

Phoenix XENCO - Master Project

Analytical Method:	**VOCs by EPA 8260B**			Prep Method:	SW5035A
Seq Number:	844840	Matrix:	Soil	Date Prep:	02/21/2011
Parent Sample Id:	406782-003	MS Sample Id:	406782-003 S	MSD Sample Id:	406782-003 SD

Parameter	Parent Result	Spike Amount	MS Result	MS %Rec	MSD Result	MSD %Rec	Limits	%RPD	RPD Limit	Units	Analysis Date	Flag
4-Methyl-2-Pentanone	<0.495	1.98	2.27	115	2.36	119	67-129	4	25	mg/kg	02/22/11 13:18	
MTBE	<0.247	1.98	2.32	117	2.38	120	62-125	3	24	mg/kg	02/22/11 13:18	
n-Propylbenzene	<0.247	0.989	1.15	116	1.15	116	51-129	0	29	mg/kg	02/22/11 13:18	
Styrene	<0.247	0.989	1.08	109	1.09	110	57-123	1	23	mg/kg	02/22/11 13:18	
1,1,1,2-Tetrachloroethane	<0.247	0.989	1.02	103	1.02	103	59-115	0	23	mg/kg	02/22/11 13:18	
1,1,2,2-Tetrachloroethane	<0.0989	0.989	1.10	111	1.11	112	45-133	1	29	mg/kg	02/22/11 13:18	
Tetrachloroethylene	<0.0495	0.989	0.983	99	0.967	98	40-125	2	26	mg/kg	02/22/11 13:18	
Toluene	<0.0989	0.989	1.02	103	1.01	102	50-125	1	28	mg/kg	02/22/11 13:18	
1,2,4-Trichlorobenzene	<0.247	0.989	1.04	105	1.06	107	31-136	2	27	mg/kg	02/22/11 13:18	
1,2,3-Trichlorobenzene	<0.247	0.989	1.04	105	1.06	107	29-135	2	33	mg/kg	02/22/11 13:18	
1,1,2-Trichloroethane	<0.0495	0.989	1.07	108	1.08	109	53-117	1	24	mg/kg	02/22/11 13:18	
1,1,1-Trichloroethane	<0.0495	0.989	1.08	109	1.11	112	47-125	3	31	mg/kg	02/22/11 13:18	
Trichloroethene	<0.0495	0.989	1.01	102	1.04	105	51-130	3	24	mg/kg	02/22/11 13:18	
Trichlorofluoromethane	<0.495	1.98	2.03	103	2.06	104	36-133	1	45	mg/kg	02/22/11 13:18	
1,2,3-Trichloropropane	<0.247	0.989	1.11	112	1.14	115	56-120	3	25	mg/kg	02/22/11 13:18	
1,2,4-Trimethylbenzene	<0.247	0.989	1.15	116	1.15	116	49-129	0	38	mg/kg	02/22/11 13:18	
1,3,5-Trimethylbenzene	<0.247	0.989	1.15	116	1.13	114	44-137	2	38	mg/kg	02/22/11 13:18	
Vinyl Acetate	<0.495	1.98	2.65	134	2.52	127	25-170	5	50	mg/kg	02/22/11 13:18	
Vinyl Chloride	<0.495	1.98	2.36	119	2.46	124	25-144	4	47	mg/kg	02/22/11 13:18	
o-Xylene	<0.0495	0.989	1.06	107	1.06	107	52-127	0	29	mg/kg	02/22/11 13:18	
m,p-Xylenes	<0.0989	1.98	2.09	106	2.09	106	51-126	0	29	mg/kg	02/22/11 13:18	

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SOUTHWEST
RESEARCH INSTITUTE

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(210) 684-5111

SHIPPING TICKET NO.
69592
(THIS IS NOT A P.O. NO.)
DATE: 02/16/11

PRIOR TO REPAIR OF ANY ITEM MENTIONED BELOW, PLEASE CONTACT 210/522-3074 WITH ESTIMATE AND FOR P.O. NO.

SHIP TO:
Xenco Laboratories
3725 E. Atlanta Ave
Phoenix, AZ 85040
Tel: 602-437-0330
ATTN: Skip Harden

VENDOR PHONE NO. | R.M.A. NO.

Please check box for method of shipment to and from Vendor
Circle specific method of shipment by Air Freight or UPS

SHIP VIA	TO VENDOR	RETURN TO SWRI
MOTOR FREIGHT	☐	☐
AIR FREIGHT (PRIORITY AIR GENERAL CARGO)	☐	☐
UPS (1 day, 2days or 7-10 days)	☐	☐
FEDERAL EXPRESS (1 day, 2 days)	☒	☐
OTHER	☐	☐

PPD. ☒ COLL ☐	INSURE FOR $ 0.00	DECLARED VALUE $ 0.00	GOVT. PROJ. ☐	DEPT NO. 08	PURCHASE ORDER NO.

AIR BILL OR W/B NO.	ACCT. OR PROJECT NO. 1.08.07.13.16246.05	SWRI REQ. NO.	RETURN INITIATED BY Hutzler/pgl	EXT.

QUANTITY	DESCRIPTION & SERIAL NO.	ORIGINAL P.O., S.O., R.O., C.O.D./REQ. NO./B/O
	EOT Date	
	JET FUEL	
1	1 - 50mL Sample Coded CL11-2183 2/17/11 sampled	
2	1 - 50mL Sample Coded CL11-2185 2/17/11 sampled	
	FLAMMABLE LIQUID	

S.W.R.I. BUYER		BUYER NOTIFIED ☐	Please indicate if items are HAZARDOUS MATERIAL ☒ YES ☐ NO
NO. OF PACKAGES 1	TYPE OF PACKAGE ☒ BOX ☐ CTN ☐ DRUM ☐ ______	WEIGHT	DIMENSIONS

REASON FOR SHIPMENT AND/OR REMARKS

☐ **REPAIR** (INDICATE PROBLEM IN REMARKS AREA) ☐ **WARRANTY** ☐ **CREDIT** ☐ **CREDIT LESS** RESTOCKING CHG. ☐ **EXCHANGE** ☐ **OTHER** (EXPLAIN IN REMARKS AREA)

REMARKS

DATE SHIPPED | VENDOR RECEIPT BY:

THIS FORM TO BE USED FOR ANYTHING SHIPPED FROM S.W.R.I.

IMPORTANT

PACKING LIST (PINK COPY) SHOULD BE ATTACHED TO THE OUTSIDE OF THE CONTAINER. REMAINDER OF SHIPPING TICKET SHOULD BE RETURNED TO SHIPPING & RECEIVING. PT.5 (GOLDENROD COPY) WILL BE RETURNED TO YOU FOR DEPARTMENT RECORDS.

rec'd from FedEx 2/18/11 @ 1005 **SHIPPING COPY** Leslie May - Xenco/Phx 18.6

Soil

Container type : 125

XENCO Laboratories

Sample Receipt Checklist

Client Name: Southwest Research

Date and Time Received: 2/18/11 1005

Work Order Number: 407165

Checked by: lm

Checklist completed by: Leslie May Date: 2/18/11

Logged In by: ____ Date: ____

Matrix: Liq Courier Name: Client Xenco FedEx

Reviewed by: ____ Date: ____

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐	
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑	
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑	
Chain of custody signed when relinquished and received? lm	~~Yes ☑~~	No ☐	Not Present ☑	
Chain of custody agrees with sample labels?	~~Yes ☑~~	No ☑		
Samples in proper container/bottle?	Yes ☑	No ☐		
Sample containers intact?	Yes ☑	No ☐		
Sufficient sample volume for indicated test?	Yes ☑	No ☐		
All samples received within holding time?	Yes ☑	No ☐		
Samples received same day of collection?	Yes ☐	No ☐	Temp: 18.6	Wet Ice Present ☐
Where was the temperature reading taken at?	Sample ☑	Temp Blank ☐	Other:	
VOA Water – VOA vials have zero headspace?	Yes ☐	No ☐	N/A ☑	
Water – Microbiological bottles have ≤ 2.5 cm headspace?	Yes ☐	No ☐	N/A ☑	
Water – All sample pH's acceptable upon receipt?	Yes ☐	No ☐	N/A ☑	Checked by: ____

If **No**, list all samples and bottle types that are not acceptable in Additional Comments section. Also state any correction actions.

Sulfide Water – Bottles have zero headspace?	Yes ☐	No ☐	N/A ☑	(zero headspace ≤ than neck of bottle)
Dissolved Water Analytes – Field Filtered?	Yes ☐	No ☐	N/A ☑	
Are samples received deemed acceptable?	Yes ☐	No ☑	If **No** then complete section below	

PC Notified Date: 2/18/11 Init: lm PC Init: ____

Client Notified Date: ____ Init: ____ L/M ☐ Date: ____ L/M ☐ Date: ____

Contact Name: ____ Action to take: Analyze ☐ Cancel ☐ Hold ☐ Other:

Changes/Comments made on original COC? Yes ☐ N/A ☐ Init: ____ Date: ____

Changes made in LIMS? Yes ☐ N/A ☐ Init: ____ Date: ____

Additional Comments: rec'd no COC - do not know date or time sampled

CS-002-SRChecklist RV5

Appendix E-5

Baseline O-Ring Data (Jet A and JP-8)

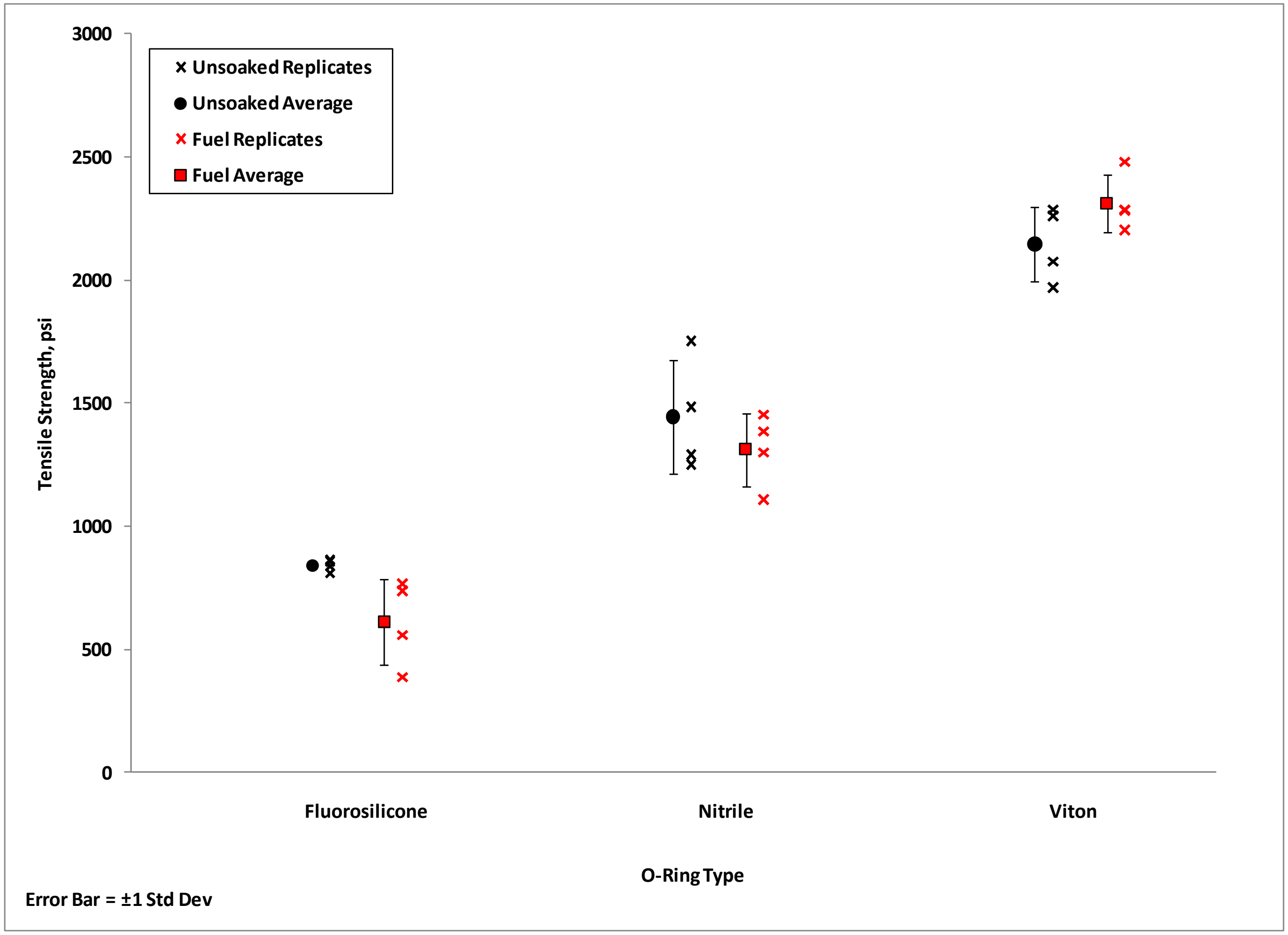

Figure E-38. Jet A O-Ring Data – Tensile Strength

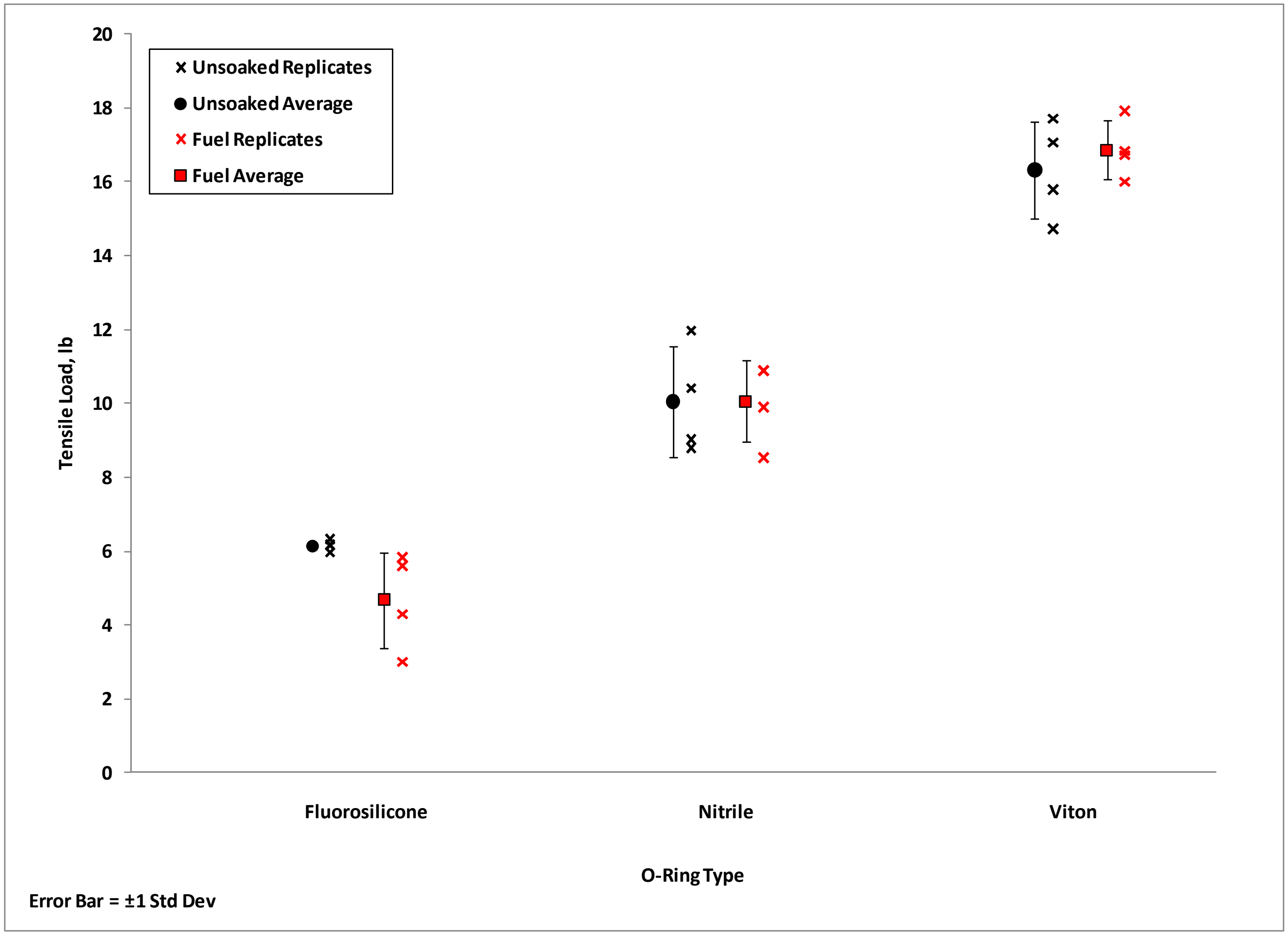

Figure E-39. Jet A O-Ring Data – Tensile Load

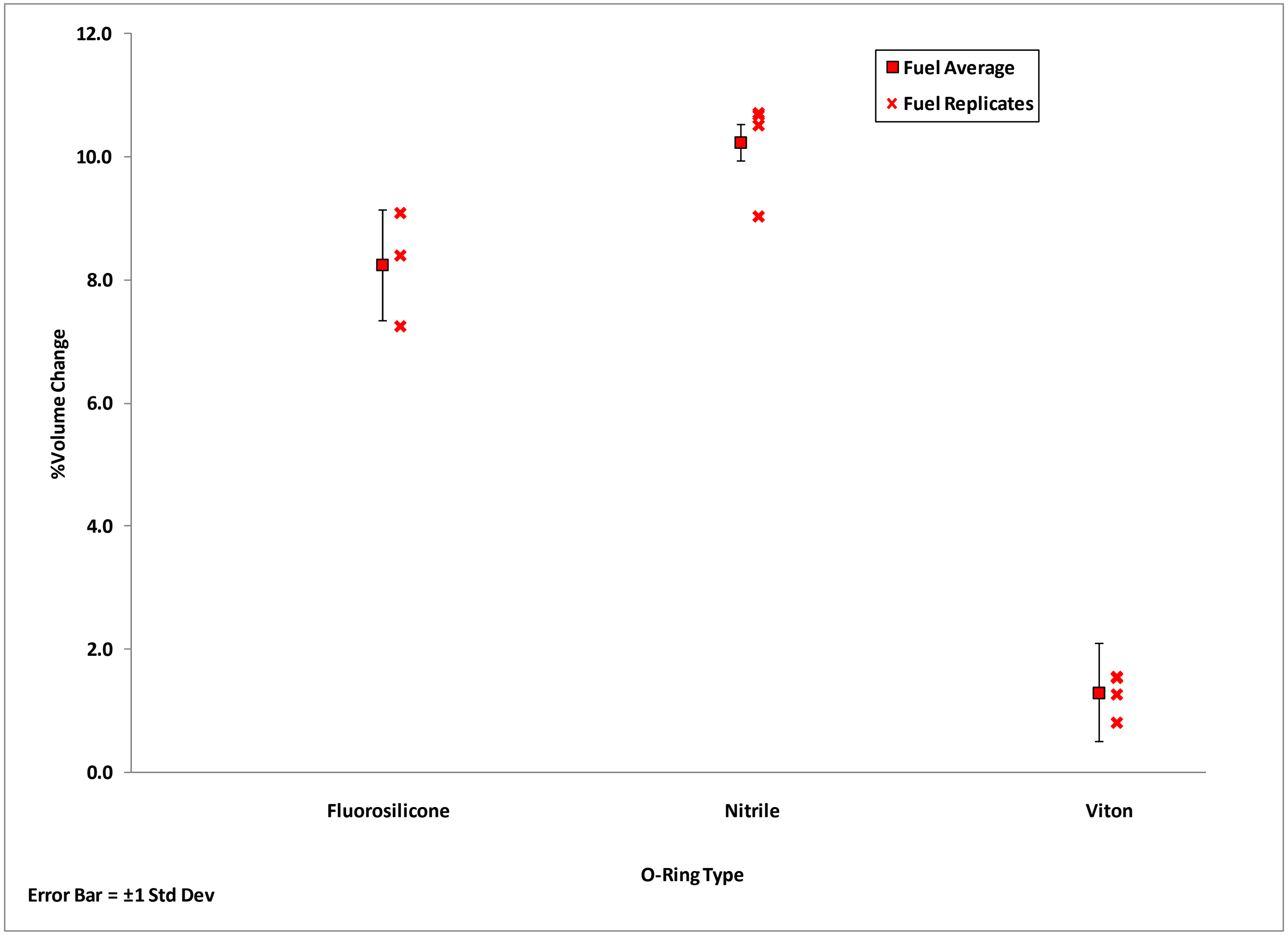

Figure E-40. Jet A O-Ring Data – Volume Change

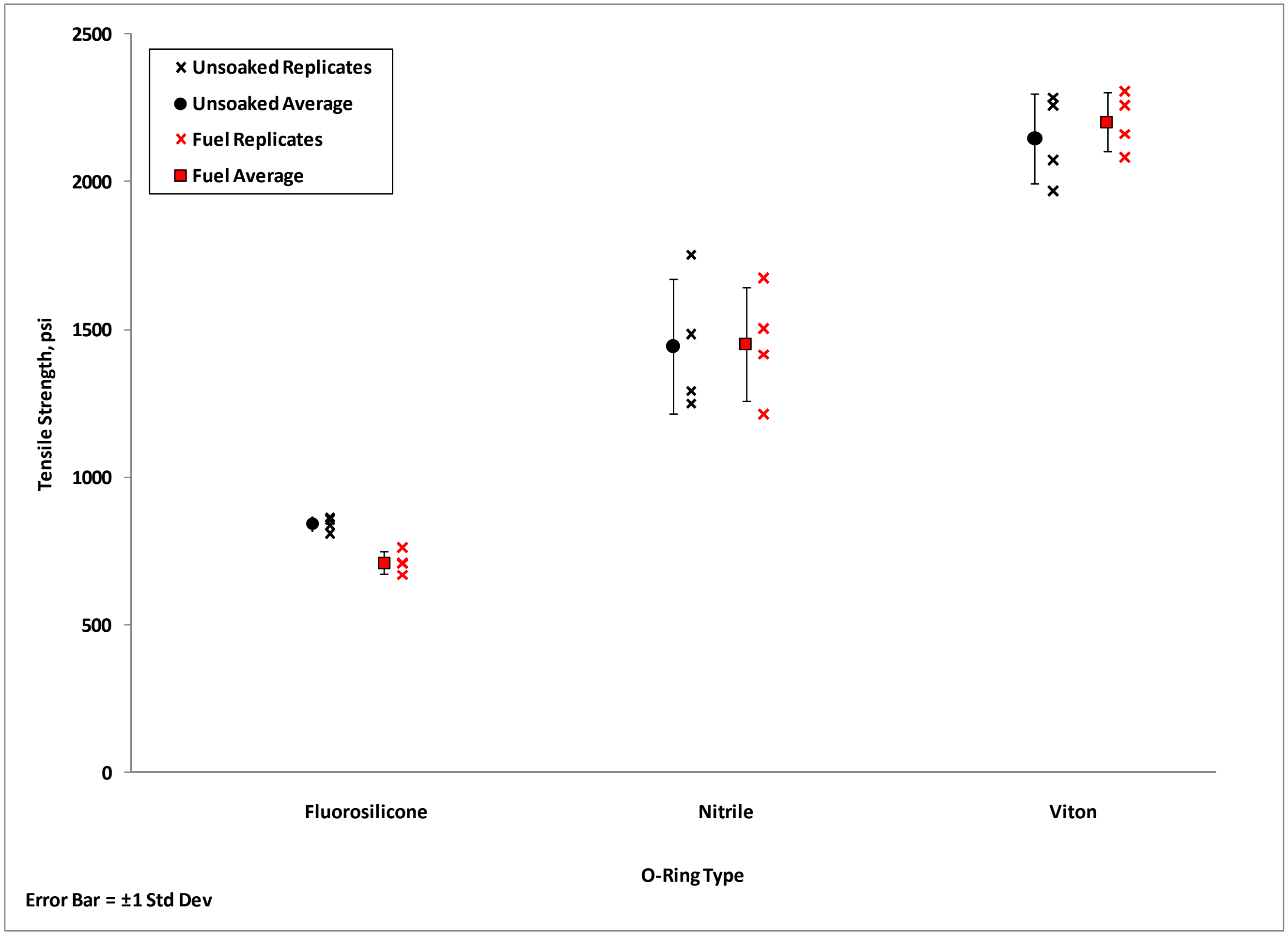

Figure E-41. JP-8 O-Ring Data – Tensile Strength

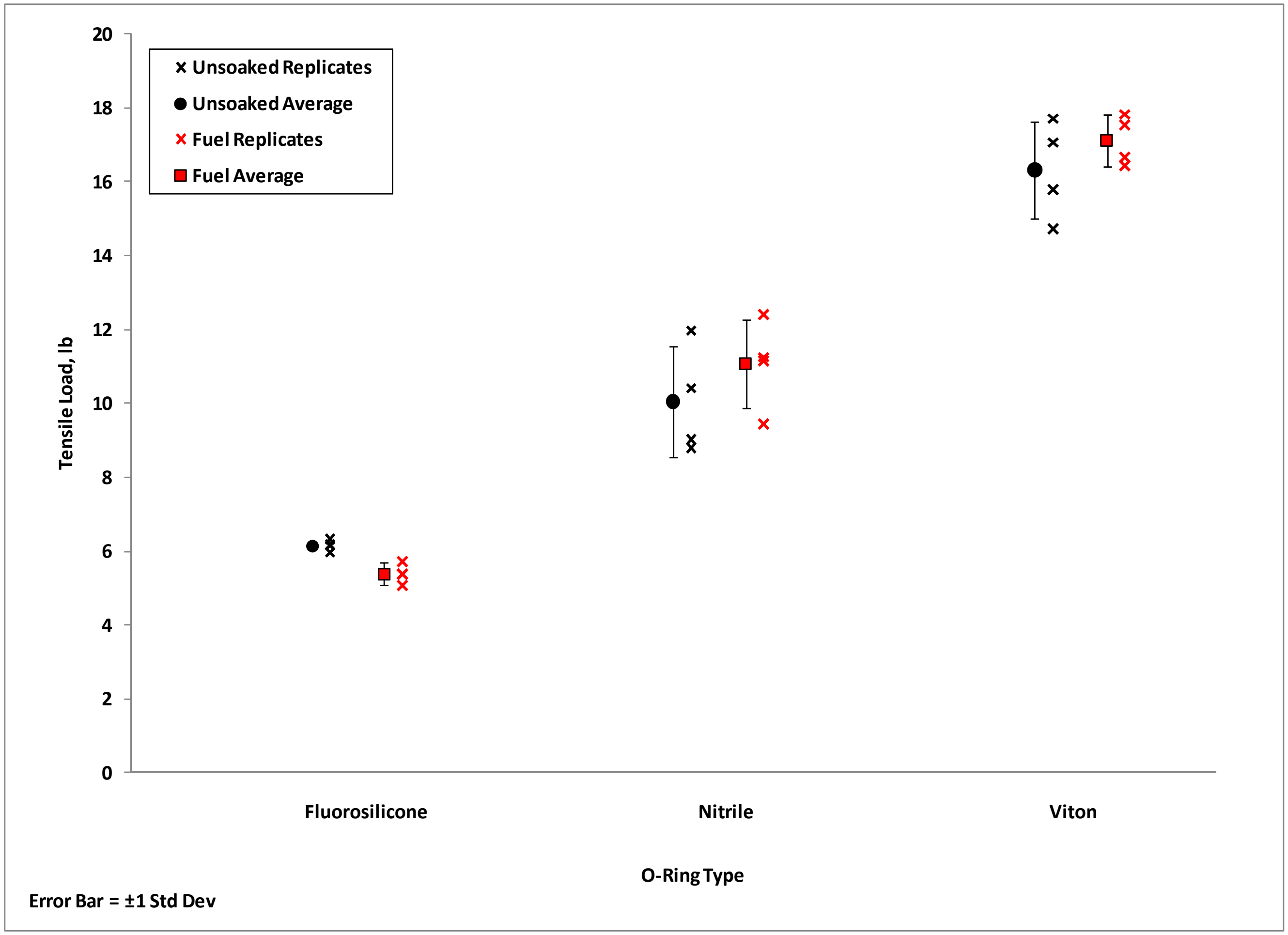

Figure E-42. JP-8 O-Ring Data – Tensile Load

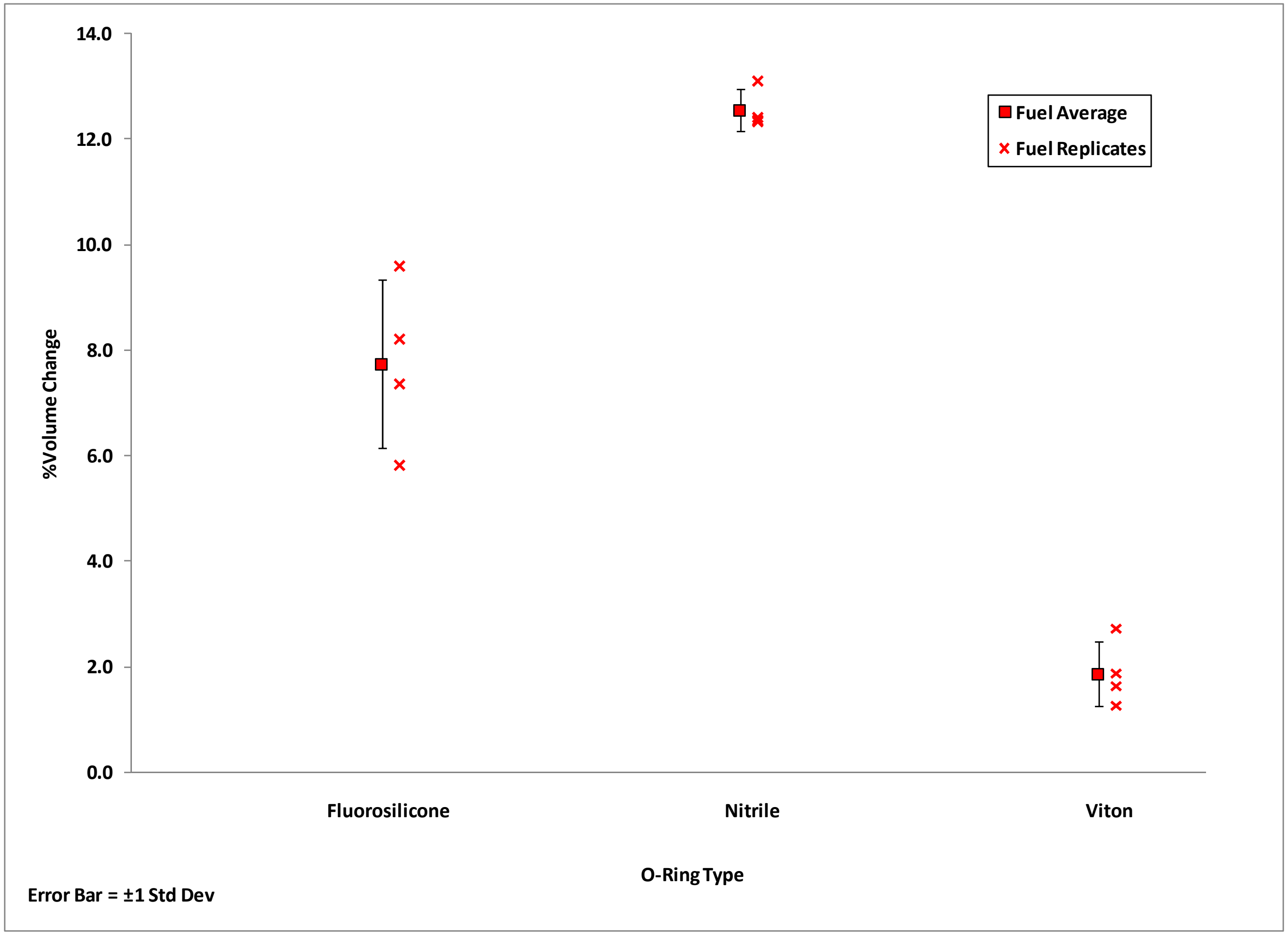

Figure E-43. JP-8 O-Ring Data – Volume Change

Appendix E-6

HFRR Lubricity Evaluations

Table E-7. Opti-Lube Lubricity Evaluation

Test	Method	Units	CL10-0796	CL10-0797	CL10-1948	CL10-1949	CL10-0429	CL10-1266
			POSF6413	POSF6412	POSF6413 + OptiLube	POSF6412 + OptiLube	Jet A	JP-8
HFRR @ 60°C	D6079	µm	660	630	660	630	720	730
	Re-run	µm	640	630				
Previous Analysis (May 2010)								
HFRR @ 60°C	D6079	µm	630	660				

Appendix E-7

FAA CLEEN Fuel Analysis Data

Table E-8. FAA CLEEN Fuel Analysis Data

Test	Method	Units	CL10-1986	CL10-1987	CL10-1988	CL10-1989
			JP-TS	JP-5	R8/JP-8	JP-8
Chemistry						
Aromatic Content	D1319					
Aromatics		vol%	15.70	10.80	8.50	17.60
Olefins		vol%	0.90	1.30	0.70	0.80
Saturates		vol%	83.40	87.90	90.80	81.60
Hydrogen Content (NMR)	D3701	mass%	14.24	14.54	14.70	14.22
Bulk Physical and Performance Properties						
Distillation	D86					
IBP		°C	158.5	189.0	160.2	171.1
5%		°C	167.0	195.9	179.1	181.4
10%		°C	167.1	198.6	183.4	182.8
15%		°C	167.5	200.6	187.3	185.0
20%		°C	168.5	202.2	190.2	186.9
30%		°C	170.2	205.9	197.3	191.0
40%		°C	172.3	209.7	204.4	195.1
50%		°C	174.9	213.5	210.6	199.9
60%		°C	178.3	217.9	218.2	205.4
70%		°C	182.9	223.6	226.4	212.1
80%		°C	190.5	231.0	237.0	219.9
90%		°C	204.8	241.0	249.8	231.1
95%		°C	220.0	250.0	259.6	240.8
FBP		°C	233.0	258.7	265.4	249.4
Residue		%	1.2	1.4	1.4	1.2
Loss		%	0.6	0.8	0.9	1.0
T50-T10		°C	7.8	14.9	27.2	17.1
T90-T10		°C	37.7	42.4	66.4	48.3
JFTOT	D3241	°C				
Test Temperature		°C	260°C	260°C	260°C	260°C
ASTM Code		rating	<2	2.0	2.0	<2
Maximum Pressure Drop		mm Hg	1	0	0	1
Lubricity (BOCLE)	D5001	mm	0.510	0.570	0.550	0.540
Kinematic Viscosity	D445					
-39.9°C		cSt	5.10	16.73	10.47	8.17
-19.95°C		cSt	2.85	6.79	4.85	4.08
0°C		cSt	1.96	3.70	2.89	2.48
20°C		cSt	1.37	2.35	1.89	1.71
40°C		cSt	1.05	1.65	1.39	1.25
Density	D4052					

Table E-8. FAA CLEEN Fuel Analysis Data

Test	Method	Units	CL10-1986	CL10-1987	CL10-1988	CL10-1989
			JP-TS	JP-5	R8/JP-8	JP-8
15°C		g/cm^3	0.7827	0.7929	0.7775	0.7935
Surface tension	D1331A					
-22.0°C		mN/m	23.7	23.9	25.0	25.5
Flash Point – Tag Closed	D56	°C	45	62	47	48
Freeze Point	D5972	°C	-65.4	-51.5	-52.8	-51.8
Electrical Properties						
Electrical Conductivity	D2624	pS/m	44 @ 16°C	8 @ 16°C	1053 @ 16°C	152 @ 16°C
Ground Handling Properties and Safety						
MSEP	D3948	rating	53	77	53	82
Copper Strip Corrosion (100°C for 2 hours)	D130	rating	1B	1B	1B	1B
Smoke Point	D1322	mm	29.5	31.5	31.5	28.5
Naphthalene Content	D1840	vol%	0.52	0.47	0.19	0.39
Sulfur – Mercaptan	D3227	mass%	<0.0003	<0.0003	<0.0003	<0.0003
Acid Number	D3242	mg KOH/g	0.035	0.020	0.001	0.003
Existent Gums	D381	mg/100mL	20	6	<1	<1
Heat of Combustion	D4809					
BTUHeat_Gross		BTU/lb	19922.4	19998.0	20148.1	19918.8
BTUHeat_Net		BTU/lb	18623.3	18671.6	18807.0	18621.6
MJHeat_Gross		MJ/kg	46.3	46.5	46.8	46.3
MJHeat_Net		MJ/kg	43.3	43.4	43.7	43.3
Sulfur Content – (XRY)	D2622	ppm	37	52	117	217

Appendix E-8

Water Solubility Study

Table E-9. Water Solubility Results

Sample ID	Description	Temperature (°C)	Water Content (ASTM D6304) ppm
CL10-0429	Jet A	-9.5	60
		43.0	213
		54.0	255
CL10-0278	Camelina HRJ	-14.5	0
		-8.0	68
		37.0	172
		54.0	237
CL11-2250	Clay-Treated (CT) Camelina HRJ	-14.5	10
		-9.0	42
		40.0	149
		50.2	*600+ (erratic)*
CL11-2252	50/50 Camelina HRJ / Jet A	-5.5	54
		38	243
		48.5	259
CL11-2254	50/50 CT Camelina HRJ / Jet A	-14.5	20
		-9.0	52
		36.0	222
		52.6	*800+ (erratic)*
CL07-0432	Sasol FT SPK	-8.0	68
		37.0	223
		51.0	356
CL11-2257	50/50 Sasol FT SPK / Jet A	-9.0	53
		43.0	183
		47.5	213
CL10-1623	Shell FT SPK	-14.5	17
		-9.0	86
		37.0	418
		45.5	*600+ (erratic)*
CL11-2256	50/50 Shell FT SPK / Jet A	-13.5	33
		-9.5	27
		38.0	173
		46.5	*400+ (erratic)*
CL10-0773	Tallow HRJ	-14.0	0
		-9.5	64
		35.0	127
		56.5	161
CL11-2251	Clay-Treated (CT) Tallow HRJ	-13.5	21
		-10.0	48
		38.0	158
		52.0	*600+ (erratic)*
CL11-2253	50/50 Tallow HRJ / Jet A	-14.0	0
		-9.0	61
		46.0	176
		52.0	203
CL11-2255	50/50 CT Tallow HRJ / Jet A	-14.5	15
		-9.0	42
		39.0	156
		51.5	237

Appendix E-9

Speed-of-Sound and Isentropic Bulk Modulus Data

Table E-10. Speed-of-Sound and Isentropic Bulk Modulus

Sample ID	Description	Speed of Sound @ 30°C m/s	Density @ 30°C g/cm^3	Isentropic Bulk Modulus @ 30°C psi
CL11-2413	Premium Ultra-Low Sulfur Diesel	1329	0.8241	210,966
CL11-2259	JP-8	1284	0.8016	191,712
CL10-0429	Jet A	1262	0.7873	181,872
CL11-2128	50/50 R8/JP-8	1267	0.7721	179,717
CL10-1818	Neste Oil NExBTL HRJ	1275	0.7603	179,293
CL11-2183	50/50 Rentech FT-SPK /JP-8	1260	0.7715	177,706
CL10-0932	50/50 Tallow HRJ /JP-8	1258	0.7697	176,642
CL10-0327	50/50 Camelina HRJ /JP-8	1247	0.7661	172,710
CL10-687	TS-1	1256	0.7497	171,479
CL11-2513	GEVO ATJ / JP-8	1231	0.7701	169,372
CL11-2127	R8 w/ JP-8 Additives (HRJ8)	1247	0.7503	169,283
CL11-2185	Rentech FT-SPK w/ JP-8 Additives	1246	0.7512	169,015
CL10-773	Tallow HRJ	1241	0.7463	166,620
CL09-0268	Sasol IPK	1212	0.7497	159,690
CL10-278	Camelina HRJ	1220	0.7391	159,600
CL11-1623	Shell FT-SPK	1205	0.7247	152,657
CL11-2512	GEVO ATJ	1181	0.7455	150,769
Cyclohexane	check sample	1228.43 (lit 1228.72)	--	--
Cyclohexane	check sample	1229.38 (lit 1228.72)	--	--
Cyclohexane	check sample	1228.47 (lit 1228.72)	--	--
Cyclohexane	check sample	1228.44 (lit 1228.72)	--	--

Appendix E-10

Certificates of Analysis (COA)

AFPET LABORATORY REPORT
HQ AFPET/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2011LA31087001	Date Received:04/21/11 0718 hrs*	Date Sampled: **
Cust Sample No:7504	Date Reported:04/27/11 1559 hrs*	Protocol:FU-AVI-0019
JON: GENERAL FUND		

Sample Submitter:
AFRL/RZPF
1790 Loop Road N
Bldg 490
WPAFB, OH 45433

Reason for Submission: AFRL Research
Product: Aviation Turbine Fuel, Kerosene
Specification: MIL-DTL-83133G Grade:JP-8

Qty Submitted: 1 gal
Batch/Lot/Origin: BIOFUEL

Method	Test	Min	Max	Result	Fail
ASTM D 2622 - 10	Sulfur (% mass)		0.30	0.0004	
ASTM D 6304-07	Water, Coulometric Karl Fischer Titration (ppmw)			14.0	
ASTM D 6045 - 09	Color, Saybolt	Report Only		+30	
ASTM D 3242 - 08	Total Acid Number (mg KOH/g)		0.015	0.004	
ASTM D 1319 - 10	Aromatics (% vol)		25.0	0.6	
ASTM D 3227 - 04a	Mercaptan Sulfur (% mass)		0.002	0.000	
ASTM D 86 - 10a	Distillation				
	Initial Boiling Point (°C)			166	
	10% Recovered (°C)		205	176	
	20% Recovered (°C)			178	
	50% Recovered (°C)			180	
	90% Recovered (°C)			198	
	End Point (°C)		300	241	
	Residue (% vol)		1.5	1.5	
	Loss (% vol)		1.5	0.6	
ASTM D 93 - 10a	Flash Point (°C)	38		47	
ASTM D 4052 - 09	API Gravity @ 60°F	37.0	51.0	55.3	X
ASTM D 4052 - 09	Density @ 15°C (kg/L)	0.775	0.840	0.757	X
ASTM D 5972 - 05e1	Freezing Point (°C)		-47	<-60	
ASTM D 445 - 10	Viscosity @ -20°C (mm²/s)		8.0	4.7	
ASTM D 3338 - 08	Net Heat of Combustion (MJ/kg)	42.8		44.0	
ASTM D 3343 - 05	Hydrogen Content (% mass)	13.4		15.2	
ASTM D 1322 - 08	Smoke Point (mm)	25.0		29.0	
ASTM D 130 - 10	Copper Strip Corrosion (2 h @ 100°C)	1 (Max)		1a	
ASTM D 3241 - 09e1	Thermal Stability @ 325°C				
	Tube Deposit Rating, Visual	<3 (Max)		0	
	Change in Pressure (mmHg)		25	1	
ASTM D 381 - 04	Existent Gum (mg/100 mL)		7.0	<1	
ASTM D 1094 - 07	Water Reaction Interface Rating	1b (Max)		1	
ASTM D 3948 - 08	WSIM	70		98	
ASTM D 2624 - 09	Conductivity (pS/m)	150	600	0	X
ASTM D 5001 - 10	Lubricity Test (BOCLE) Wear Scar (mm)	Report Only		0.87	
ASTM D 4809 - 09a	Net Heat of Combustion (MJ/kg)	42.8		43.9	
ASTM D 1319 - 10	Olefins (% vol)	Report Only		0.4	
MIL-DTL-83133G	Workmanship			Pass	
ASTM D 445 - 10	Viscosity @ 40°C (mm²/s)	Report Only		1.5	

Dispositions:
For information purposes only.

* Date reflects Eastern Standard Time(EST) | Report Generated: 04/27/11 15:59*
** Date as provided by customer

AFPET LABORATORY REPORT
HQ AFPET/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2011LA31087001	Date Received:04/21/11 0718 hrs*	Date Sampled: **
Cust Sample No:7504	Date Reported:04/27/11 1559 hrs*	Protocol:FU-AVI-0019
JON: GENERAL FUND		

Sample Submitter:
AFRL/RZPF
1790 Loop Road N
Bldg 490
WPAFB, OH 45433

The analyzer was unable to detect any wax crystal after reaching its low temperature limit at -76°C. ASTM D 5972 freeze point is estimated to be <-60°C.

Approved By	Date
Miguel Acevedo, Chief \\SIGNED\\	04/27/2011*

This report was electronically delivered to:
donald.minus@wpafb.af.mil, jennifer.engelman@wpafb.af.mil, linda.shafer@wpafb.af.mil, miguel.acevedo@wpafb.af.mil, rhonda.cook@wpafb.af.mil, richard.wilkes@wpafb.af.mil

* Date reflects Eastern Standard Time(EST) | Report Generated: 04/27/11 15:59*
** Date as provided by customer

AFPET LABORATORY REPORT
HQ AFPET/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2011LA31088001 Date Received:04/21/11 0733 hrs* Date Sampled: **
Cust Sample No:7505 Date Reported:04/26/11 1002 hrs* Protocol:FU-AVI-0019
JON: GENERAL FUND

Sample Submitter:
AFRL/RZPF
1790 Loop Road N
Bldg 490
WPAFB, OH 45433

Reason for Submission: AFRL Research
Product: Aviation Turbine Fuel, Kerosene
Specification: MIL-DTL-83133G Grade:JP-8

Qty Submitted: 1 gal
Batch/Lot/Origin: BIOFUEL/JP-8 BLEND

Method	Test	Min	Max	Result	Fail
ASTM D 2622 - 10	Sulfur (% mass)		0.30	0.01	
ASTM D 6045 - 09	Color, Saybolt	Report Only		+19	
ASTM D 3242 - 08	Total Acid Number (mg KOH/g)		0.015	0.005	
ASTM D 1319 - 10	Aromatics (% vol)		25.0	10.2	
ASTM D 3227 - 04a	Mercaptan Sulfur (% mass)		0.002	0.001	
ASTM D 86 - 10a	Distillation				
	Initial Boiling Point (°C)			168	
	10% Recovered (°C)		205	177	
	20% Recovered (°C)			181	
	50% Recovered (°C)			190	
	90% Recovered (°C)			236	
	End Point (°C)		300	260	
	Residue (% vol)		1.5	1.3	
	Loss (% vol)		1.5	0.6	
ASTM D 93 - 10a	Flash Point (°C)	38		49	
ASTM D 4052 - 09	API Gravity @ 60°F	37.0	51.0	50.0	
ASTM D 4052 - 09	Density @ 15°C (kg/L)	0.775	0.840	0.780	
ASTM D 5972 - 05e1	Freezing Point (°C)		-47	-57	
ASTM D 445 - 10	Viscosity @ -20°C (mm^2/s)		8.0	4.5	
ASTM D 3338 - 08	Net Heat of Combustion (MJ/kg)	42.8		43.6	
ASTM D 3343 - 05	Hydrogen Content (% mass)	13.4		14.4	
ASTM D 1322 - 08	Smoke Point (mm)	25.0		25.5	
ASTM D 1840 - 07	Naphthalenes (% vol)		3.0	0.5	
ASTM D 130 - 10	Copper Strip Corrosion (2 h @ 100°C)	1 (Max)		1a	
ASTM D 3241 - 09e1	Thermal Stability @ 260°C				
	Change in Pressure (mmHg)		25	0	
	Tube Deposit Rating, Visual	<3 (Max)		1	
ASTM D 381 - 04	Existent Gum (mg/100 mL)		7.0	1.0	
ASTM D 1094 - 07	Water Reaction Interface Rating	1b (Max)		1	
ASTM D 3948 - 08	WSIM	70		62	X
ASTM D 5006 - 10e1	FSII (% vol)	0.10	0.15	0.11	
ASTM D 2624 - 09	Conductivity (pS/m)	150	600	186	
ASTM D 5001 - 10	Lubricity Test (BOCLE) Wear Scar (mm)	Report Only		0.53	
ASTM D 4809 - 09a	Net Heat of Combustion (MJ/kg)	42.8		43.4	
ASTM D 1319 - 10	Olefins (% vol)	Report Only		0.6	
MIL-DTL-83133G	Workmanship			Pass	
ASTM D 445 - 10	Viscosity @ 40°C (mm^2/s)	Report Only		1.4	

Dispositions:

* Date reflects Eastern Standard Time(EST) | Report Generated: 04/26/11 10:02*
** Date as provided by customer

AFPET LABORATORY REPORT
HQ AFPET/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2011LA31088001	Date Received:04/21/11 0733 hrs*	Date Sampled: **
Cust Sample No:7505	Date Reported:04/26/11 1002 hrs*	Protocol:FU-AVI-0019
JON: GENERAL FUND		

Sample Submitter:
AFRL/RZPF
1790 Loop Road N
Bldg 490
WPAFB, OH 45433
For information purposes only.

Approved By	Date
Miguel Acevedo, Chief \\SIGNED\\	04/26/2011*

This report was electronically delivered to:
donald.minus@wpafb.af.mil, jennifer.engelman@wpafb.af.mil, linda.shafer@wpafb.af.mil, miguel.acevedo@wpafb.af.mil, rhonda.cook@wpafb.af.mil, richard.wilkes@wpafb.af.mil

* Date reflects Eastern Standard Time(EST) | Report Generated: 04/26/11 10:02*
** Date as provided by customer

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

Acronym	Description
ABW	Air Base Wing
AFRL	Air Force Research Laboratory
ATJ	Alcohol-to-Jet
BOCLE	Ball-On Cylinder Lubricity Evaluator
CI/LI	corrosion inhibitor/lubricity improver
COTS	Commercial off-the-shelf
DoD	Department of Defense
DTIC	Defense Technical Information Center
FT	Fischer-Tropsch
HPCR	High Pressure Common Rail
HRJ	Hydrotreated Renewable Jet
IPK	Iso-Paraffinic Kerosene
JP-8	Conventional Jet Fuel
PA	Public Affairs
R8, Camelina and Tallow HRJ	Alternative Fuels
R&D	Research and Development
RQ (RZ)	Aerospace Systems Directorate (Propulsion Directorate)
RQP	Power Division
RQPF	Fuels & Energy Branch
SPK	Synthetic Paraffinic Kerosene
SwRI	Southwest Research Institute
TWVC	Tactical Wheeled Vehicle Cycle
UTC	Universal Technology Corporation
WPAFB	Wright-Patterson Air Force Base